THE RELATIONSHIP BETWEEN THE BUNKIE-TEST AND SELECTED BIOMOTOR ABILITIES IN ELITE-LEVEL RUGBY PLAYERS

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously, either in its entirety or in part, submitted it to any university for a degree.

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ABSTRACT

The purpose of this exploratory study was to assess the fascia alignment in kinetic muscle chains and to determine the relationship between these results and selected biomotor abilities in rugby players. It is suggested that restrictions in the fascia along the kinetic chains inhibit muscle function and therefore influence movement patterns, such as those required by skilled rugby players.

The isometric Bunkie-test was used to assess fascia alignment in ten kinetic chains related to movement patterns. Standard functional tests were used to assess agility, speed, speed endurance, lower body explosive power and upper body muscle endurance. The relationship between fascia alignment and injury occurrence was also determined. The subjects (n = 121) were all elite-level rugby players from three rugby academies. They participated voluntarily in a once-off assessment, consisting of the Bunkie-test, an Illinois agility test, a 10m sprint test, a 40m sprint test, a repeated sprint test, a vertical jump test and a maximum pull-ups test. Subjects also completed an injury questionnaire regarding all previous and current injuries. No intervention was applied and the statistical analysis was based on this assessment.

Numerous significant relationships ($p < 0.05$) were found between the results of the Bunkie-test and results of the performance tests. Players performing better on the Bunkie-test demonstrated better biomotor abilities. Very few significant findings ($p < 0.05$) were found when comparing the results of the Bunkie-test to injury occurrence.

The conclusion was made that restrictions in the fascia of kinetic chains, as determined by the Bunkie-test, could influence a rugby player's ability to perform biomotor movements optimally. Whether restrictions in the fascia resulted in an increased injury occurrence could not be shown. The Bunkie-test might be a tool for coaches and rehabilitation therapists to identify weaknesses and imbalances in the kinetic chains of athletes. Addressing these problems could then lead to improvements in sport performance.

Key words: fascia, Bunkie-test, biomotor abilities, rugby players

OPSOMMING

Die doel van hierdie ondersoekende studie was om die belyning van die fascia in kinetiese spierkettings te evalueer, asook om die verhouding tussen hierdie resultate en geselekteerde biomotoriese vermoëns in rugbyspelers. Daar is aanduidings dat beperkings in die fascia van enige spierketting spierfunksie kan inhibeer en dus ook die effektiwiteit van bewegingspatrone kan beïnvloed.

Die isometriese Bankie-toets is gebruik om die fascia belyning in tien spierkettings te evalueer. Hierdie spierkettings is belangrik vir die uitvoer van algemene bewegingspatrone. Standaard funksionele toetse is gebruik om ratsheid, spoed, spoed-uithouvermoë, eksplosiewe krag van die onderste ledemate en spieruithouvermoë van die bolyfspiere te bepaal. Die verwantskap tussen fascia belyning en die aantal beserings in rugbyspelers is ook bepaal. Die proefpersone (n = 121) was almal elite-vlak rugbyspelers verbonde aan een van drie rugby akademies. Alle spelers het vrywillig deelgeneem aan die studie. Toetsing is eenmalig gedoen en het bestaan uit die Bankie-toets, die Illinois ratsheidstoets, 'n 10m spoedtoets, 'n 40m spoedtoets, 'n herhaalde-spoed toets, 'n vertikale sprong toets en 'n maksimale optrektoets. Spelers het ook 'n vraelys aangaande huidige en vorige beserings ingevul. Geen intervensie is in hierdie studie gedoen nie en die statistiese analise was dus op die bogenoemde gebaseer.

Verskeie beduidende verwantskappe ($p < 0.05$) is gevind tussen die resultate van die Bankie-toets en die resultate van die funksionele toetse. Spelers wat beter resultate in die Bankie-toets verkry het, het ook beter biomotoriese vermoëns getoon. Min beduidende resultate ($p < 0.05$) is gevind tussen die resultate van die Bankie-toets en die voorkoms van beserings.

Die gevolgtrekking is gemaak dat beperkinge in die fascia van spierkettings, soos deur die Bankie-toets bepaal, wel 'n rugbyspeler se vermoë om biomotoriese bewegings optimaal uit te voer kan beïnvloed. Of beperkinge in die fascia ook aanleiding gee tot 'n toename in aantal beserings kon nie met hierdie studie vasgestel word nie. Die Bankie-toets kan moontlik 'n instrument vir afrigters en rehabilitasie-terapeute wees. Die doel daarvan sal wees om beperkinge en wanbalanse in spierkettings van atlete te bepaal. Indien hierdie probleme aangespreek word, behoort sportprestasie te verbeter.

Sleutelwoorde: fascia, Bankie-toets, biomotoriese vermoëns, rugbyspelers

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INTRODUCTION

As higher-level sport participation becomes more competitive, the modern athlete is confronted with increasingly intensive training regimes in order to perform optimally. Trainers, coaches and rehabilitation therapists, such as Biokineticists, are consequently challenged to design exercise and rehabilitation programs not only to enhance performance but also minimize the risk of injury. One integral aspect that forms part of training, injury prevention and rehabilitation, and cannot be disregarded, is muscle function and its role in biomotor abilities, performance and injuries (Beam, 2002; De Witt & Venter, 2009).

Researchers and scientists are constantly investigating muscle function and factors that might influence muscle function. In recent years, increasing focus has been placed on the role the surrounding connective tissue structures play in muscle function. The fascia, a type of connective tissue with unique properties, has raised interest regarding its influence on the biomechanics of the body. Two international fascia congresses held recently confirm the interest in this field (1st International Fascia Congress, Boston, 4-5 October 2007; 2nd International Fascia Congress, Amsterdam, 27-30 October 2009).

To measure muscle function in movements and in isolation, coaches and therapists currently make use of functional performance tests and muscle strength and muscle endurance tests (Baker & Newton, 2008; Gabbett, 2002a; Gabbett, 2002b; Gabbett & Domrow, 2005). The results of these tests indicate the biomotor and performance abilities of players and are typically used by coaches to choose the best players for a team. Similarly, therapists also use these tests in determining the readiness of athletes in returning to their sport. Research confirmed that muscles function in kinetic chains to perform movements, but very little attention is given to testing the function of muscles in their kinetic chains, especially among sports people (Myers, 2001; Myers, 2009). These chains consist of the muscles and the surrounding, linked connective tissue or fascia. Various isometric tests are used to assess endurance and balance of kinetic muscle chains (McGill, 2002; Nesser, Huxel, Tincher & Okada, 2008), but these are mostly isolated tests and do not assess the kinetic chains of the whole musculoskeletal system related to movement patterns. The Bunkie-test, designed by a physiotherapist from South Africa, Benita de Witt, attempts to assess kinetic chains along the linked connective tissue or fascia. Although the Bunkie-test has been used for a number of years, it has not been scientifically tested (Brumitt, 2009; De Witt & Venter, 2009). No other tests could be found to assess the function and balance of the kinetic chains related to most movement patterns.

Coaches and therapists might argue that isometric testing does not simulate the movement patterns used in sports and is not an applicable test for sports people, but as kinetic chains do exist and movement takes place by the activation of muscles along these chains, this aspect cannot be ignored. Tests for the function of kinetic chains should therefore be included in a comprehensive test battery for athletes.

As muscle imbalances and poor or wrong activation of muscles in their kinetic chains are seen as a major cause of injuries (Myers, 2001; Myers, 2009) there is a need for a scientific testing tool in the rehabilitation practice of a Biokineticist. This test should not require expensive equipment and must be relevant for athletes. If the function of the kinetic chains can be assessed, it could assist the Biokineticist in determining when athletes are ready to resume their sport. No studies have been conducted to investigate the relationship between the function of kinetic chains or tests for kinetic chains and biomotor abilities or performance. An attempt is made in this study to find a possible cause for poor biomotor abilities and performance in athletes. This research also aims to identify a possible link between fascia restrictions along kinetic chains and selected biomotor abilities in athletes.

AIM OF THE STUDY

The aim of this study is to use the above-mentioned Bunkie-test to assess the function of the kinetic chains, and to determine the relationship between the Bunkie-test and biomotor abilities in rugby players.

RESEARCH QUESTIONS

The following research questions have been addressed in this study:

- Is there a relationship between fascia restrictions, as assessed by the Bunkie-test, and selected biomotor abilities in rugby players?

- Is there a relationship between fascia restrictions, as assessed by the Bunkie-test, and injury occurrence in rugby players?
- Is there a relationship between fascia restrictions, as assessed by the Bunkie-test, and the site(s) of injury in rugby players?

OUTLINE OF THESIS

Chapter two consists of the theoretical background for this study and reviews current literature and related studies on fascia, muscle function, rugby as a sport and injuries in rugby. In chapter three the specific methods for data collection are discussed. The results of all the statistical procedures are presented in chapter four. Chapter five contains a discussion of the results found, as well as a conclusion to this study, limitations of this study, and recommendations for future studies.

TERMINOLOGY

1. **Myofascial trigger point:** Defined by Travell and Simons (1983: 7) as "a hyperirritable spot, usually in a taut band of skeletal muscle or in the muscle's fascia. It is painful on compression and can give rise to characteristic referred pain (each has its specific area of reference), tenderness and autonomic phenomena". It has a direct influence on muscle functioning by preventing optimal lengthening of the muscle and therefore weakening the muscle (Travell & Simons, 1983: 7).

2. **Anatomy trains:** A series of muscles and fascia (myofascia) all linked and functioning together to create specific movements. A change in one part of the train will indirectly affect the whole train (Myers, 2001; Myers, 2009).

3. **Muscle imbalance:** A difference in the strength of antagonistic muscles, for example one muscle being strong and the opposing muscle being weak. This can cause alignment problems and inefficient movements (Kendall *et al.,* 1993: 416).

4. **Myofascia:** Muscle tissue and its intertwined and surrounding fascia (connective tissue) (Myers, 2001: 3).

5. **Myofascial continuity:** The myofascia is continuous through the body, linking all aspects of muscles and also two adjacent and aligned structures (Myers, 2001: 5).

6. **Tensegrity:** This is also known as tension integrity. “The connective tissue framework, in conjunction with active muscles, provides another kind of tensional force that is crucial to the upright structure of the skeleton” (Chaitow, 2007: 42).

CHAPTER TWO
REVIEW OF LITERATURE

The structure and properties of fascia as a type of connective tissue is reviewed in this chapter. The role of fascia in muscle function and the involvement of fascia in injuries are discussed. The existence of kinetic chains or muscular systems in which muscles function optimally are discussed, as well as the relationship of these kinetic chains to biomotor abilities and injuries. The high injury occurrence in rugby and the popular use of functional performance tests among rugby players are included, as rugby players were used as subjects in this study.

THE STRUCTURE OF FASCIA

Connective tissue, as the name implies, connects everything in the body, from bones to muscles, to organs (Myers, 2001: 13). Ligaments and tendons are classified as dense, regular connective tissues, while fascia is classified as a dense, irregular connective tissue, implying that it is able to stretch in any direction (Cantu & Grodin, 1992: 36; Schleip, 2003a: 11). There is, however, still some disagreement on these classifications (Stecco, Porzionato, Lancerotto, Stecco, Macchi, Day, & Caro, 2008: 225). All connective tissue, including fascia, consists of collagen fibers, elastin fibers and a ground substance between the fibers (a polysaccharide gel complex). Collagen is the main component of fascia and provides strength, support and stability to these tissues. This ensures that it will not easily give way under tension. This is one of the most important characteristics of fascia (Huijing, 1999a: 331). The elastic nature of the elastin allows dynamic flexibility of the fascia, while the ground substance gel absorbs shocks and compressive forces from movements and distributes it through the body (Barnes, 1990: 4). Fascia is described as a tissue with a higher degree of tensile strength and a lesser degree of extensibility (Hertling & Kessler, 2005: 129).

According to Kendall *et al*. (1993: 336), fascia is divided into superficial and deep fascia. The fibro-elastic superficial fascia is situated just beneath the skin, allows movement of the skin and provides shape to the body. The deep fascia is a dense fibrous fascia and is situated around and in-between muscles, bones, nerves and blood vessels (LeMoon, 2008b: 211). Stecco *et al*. (2008: 226) also divided the fascia into the superficial and deep layer with the same characteristics as Kendall's layers, but Manheim (1994: 13) added a third layer between the superficial and deep layers, called a 'potential space'. The significance of this space between the layers is that it enables the fascia to enlarge when swelling is evident. As swelling or edema is normally associated with the body's response to injuries, this effect can imply that the normal structure of fascia can be disrupted and deformed in the case of an injury.

The connective tissue layer around all myofibrils or individual muscle cells is called the endomysium, while the layer around the muscle bundles is known as the perimysium and the layer around an entire muscle is the epimysium. These three layers are all extensions of the deep fascia (Cantu & Grodin, 1992: 39; Huijing, 1999a: 331; Järvinen, Józsa, Kannus, Järvinen & Järvinen, 2002: 245). The endomysium, perimysium and epimysium are all connected to each other and to the surrounding fascia, forming a continuous structure or network (Barnes, 1990: 3). The endomysium around the muscle cells plays an important role in muscle flexibility, while the perimysium around the muscle bundles is considered as protective tissue or, according to newer research, is important in transmitting mechanical forces laterally in the musculoskeletal system (Passerieux, 2007: 27).

FASCIA PROPERTIES AND THE SIGNIFICANCE THEREOF

A three-dimensional network

Many scientists described the fascial system as a three-dimensional connective tissue network throughout the body (Barnes, 1990: 3; Chaitow, 2007: 42; Myers, 2001: 13; Myers, 2009; Schleip, 2003a: 11). This network provides shape and structure to the body, envelops all muscles, helps the body to resist mechanical stresses by providing support and protection, and regulates movement between adjacent structures (Barnes, 1990: 3; Hertling & Kessler, 2005: 130).

Myofascia – the muscle and fascia connection

Hertling and Kessler (2005: 148) described the myofascial connection by explaining that skeletal muscle is made up out of two components, the contractile fibers and connective tissue. They even stated that "skeletal muscle, for all practical purposes, does not exist without fascia". Muscles are responsible for initiating and performing movement with the help of input from the central nervous system, while the fascia stabilizes the musculoskeletal system and allows movement (Hertling & Kessler, 2005: 130). The researchers also emphasized that fascia "is vitally involved in all aspects of motion". All muscles are thoroughly intertwined and surrounded by fascia, explaining why fascia might have a significant influence on muscle length and function (Barnes, 1990: 3). As a result of this close association, dysfunctions of fascia in certain areas can affect muscle function negatively. The opposite is also true, as muscle dysfunctions can also influence fascia negatively.

Cantu and Grodin (1992: 39) noted the importance of the myofascia and emphasized the fact that movement and its associated mechanical forces affect both muscle and fascia. Movement and force shape and remodel the fascia, probably to strengthen or thicken certain areas which are more often under strain. Manheim (1994: 36) compared the fascia of the lower limbs to that of the upper limbs and found the fascia of the lower limbs to be better developed, as it is more involved in producing movement in humans than the upper limbs. Stecco, Masiero, Macchi, Stecco, Porzionato and De Caro (2009: 256) also found that the distribution and features of fascia differs throughout the body.

In a study by Järvinen *et al*., (2002: 245) the changes in the connective tissue surrounding muscles were observed after immobilizing the hind limbs of rats for three weeks. The aim of this study was to determine the effects of fascia on muscle, especially after injury. Considerable changes in the orientation of the collagen fibers were noted in the perimysium and endomysium after the three weeks of immobilization. The disruption of the normal fiber orientation was so severe that it restricted movement of the muscle fibers and prevented lengthening of a muscle when needed. This study confirmed the important relationship between fascial connective tissue and muscle function. The conclusion was that immobilization of a joint or muscle after an injury can have a significant effect on muscle functioning, due to changes in connective tissue.

In a recent study, Stecco (2009: 56) dissected 15 cadavers to examine the continuity of the fascial connective tissue and the relationship between muscle and fascia of the upper arm. In the upper limbs of all the cadavers he found a continuous sheath of fascia covering all the muscles of the arm and connecting the upper body muscles in the flexor region. Continuity was found between all the muscles involved in movement in the same direction, which confirmed the viewpoint of Myers (2001, 2009) and his concepts of Anatomy Trains. The contractions or expansions of each muscle had a direct influence on the surrounding fascia. As a result of the continuity of the fascia, movement in one muscle could be communicated along the fascial sheath to any adjacent muscle(s). The force of a muscle contraction was transmitted along the fascial continuity. For example, if flexion of the forearm was performed, the force was transmitted along all the flexor muscles of the upper limb (Stecco, 2009: 59).

Dissecting the lower limbs of ten cadavers, Fourie (2008b: 5) identified an important interaction of the fascia with the thigh muscles. He also found the distribution of the fascia to play an important role in coordinating the functions of these muscles.

Tensegrity

The myofascia framework, together with bones, forms the upright structure of the body. The connective tissue acts as tension cables keeping the skeleton in its upright form. Perfectly balanced skeletal, muscular and connective tissue systems are necessary for stability and efficient movement of the body (Chaitow, 2007: 42; Myers, 2001: 139). A tensegrity structure (the human body in this case) is designed to distribute stress or force on one area to the whole structure. Chaitow (2007: 42) described this as a very valuable structure, as it can absorb more force and is able to adapt to continuous force.

According to Oschman (1997: 306), the body has only one stable position that does not place any unnecessary strain on the bones, muscles or connective tissues. The body is able to establish energy-efficient dynamic stability for most movements, relying on different tensions in the tensegrity structure. In each of these dynamic stability movements the muscles required should function optimally, but due to factors such as repetitive movements unto fatigue, overload and injuries, the body is often under immense pressure to maintain these stabilities without having to compensate. Compensation in either the muscular system or the connective tissue system will take place as soon as there are any deviations from these optimally balanced positions. If one area of this interconnected system is subjected to strain (caused by fatigue, overload or injury), inevitably another area will also become strained. More compensation is then needed to continue balancing all the structures successfully (Oschman, 1997: 306).

Myers (1997a: 93) described the fascial network as one structure that will continue to communicate any mechanical strains through the whole body, even if its shape or structure has been altered by injuries or trauma. All individual muscles form part of this myofascial network and thus function together.

Ingber (2008: 199) perceived the tensegrity principle as the carefully balanced tension of opposing bones and muscles, together maintaining a specific structure, whether it is an upright posture or any other position of the body. The body is balanced in most stationary positions, but movement adds tension and needs to be distributed through the body to regain balance. The greatest advantage and possibly disadvantage of this balanced musculoskeletal system is that one area under strain will not absorb all impact alone, as force will naturally be distributed and all parts of the structure will be affected.

Kassolik, Jaskólska, Kisiel-Sajewicz, Marusiak, Kawczyn´ski and Jaskólski (2009: 166) recently conducted a study to investigate the transmission of tension through the body, based on the principle of tensegrity. A short massage was repeated three times on each of the 33 participants. The brachioradialis muscle was massaged to determine if it had any effect on activity of the middle deltoid muscle, while the peroneal muscles were massaged to determine the response of the tensor fasciae latae. Neither of these muscles is connected directly, but indirectly through the tensegrity model and the connective tissue framework. The deltoid and tensor fasciae latae muscles responded to the massages of the brachioradialis and peroneal muscles respectively. This study confirmed the principle of tensegrity and the connection of the muscular system via the fascial system (Kassolik *et al.*, 2009: 170).

Fascia adaptability and force transmission

An important characteristic of fascia relevant to this current study is its ability to adapt to external stressors, such as mechanical stress or repetitive forces (Schleip, 2003a: 11). The viscoelastic properties of fascia provides it with the ability to withstand mechanical forces through its elasticity, but also explains the need to distribute these forces due to its viscous nature (Järvinen *et al.*, 2002: 245). As mentioned earlier, the gel matrix of the fascia will absorb and distribute the compressive forces of movement if these forces are not too great. According to Barnes (1990: 4), restricted fascia (due to an injury or repetitive strain on the fascial network) can still absorb shock, but cannot successfully distribute these forces. Therefore, the area where the impact is taken will have to absorb most of the force. Even a small force not being distributed is enough to cause injury. Barnes (1990: 4) emphasized that loose, movable fascia without restrictions are a prerequisite for effective movement and biomechanical functioning.

Huijing (1999a: 343) reviewed a number of studies on myofascial force transmission, concluding that some of the force on a muscle will be transmitted via the myofascial network and not only via the tendons. In another review article, Huijing (1999b: 309) compared the various methods of force transmission from the muscles. Although the author found it to be a complicated system, he again emphasized that force from the muscle is transmitted to the bone via the fascial connective tissue.

In an experimental study, Yucesoy, Koopman, Baan, Grootenboer and Huijing (2003a: 1810) examined myofascial force transmission in rats. They found that the transmission of force along the myofascia played an important role in muscle functioning, muscle length and the amount of force the muscles could generate. Another important conclusion from their study was that the condition of the intermuscular fascia had a significant effect on muscle function.

Myofascial trigger points

Myofascial trigger points have first been identified and defined by Travell and Simons (1983: 7). A trigger point develops as the result of repetitive microtrauma, overuse, muscular strain or an acute injury and can develop in any muscle. Weakness, tightness and restricted movement have been observed in muscles and connective tissue with trigger points (Han & Harrison, 1997: 92). The resulting weakness in the muscle is due to the body's protective mechanism to prevent painful muscle contractions when a trigger point is present. This leads to a decreased efficiency of muscle contraction (Travell & Simons, 1983: 16). Trigger points are a source of musculoskeletal dysfunction. As muscle activation is delayed, muscle contraction is less efficient and motor control is affected. The function of other muscles in the kinetic or functional chain will be affected indirectly. This can predispose the athlete to injury (Lucas, Polus & Rich, 2004: 165).

Other fascia properties

The ability of fascia to contract due to the inclusion of smooth muscle cells in these tissues is another significant property of fascia. It was first observed by Yahia *et al.* (1993: 425), and confirmed by Schleip (2003b: 108) years later. They both found this to have important implications for the function of fascia, as fascia is then no longer only a structure conforming to tension and pressure, but can also contract without the help of the intertwined skeletal muscles. This will greatly affect musculoskeletal functioning. Unfortunately more research is needed to confirm this finding and specify the exact effects thereof.

As mentioned previously, fascia is able to stretch in any direction because of its irregular connective tissue structure (Cantu & Grodin, 1992: 36; Schleip, 2003a: 11). Manheim (1994: 14) also noted the almost disorganized structure of fascia, with fibers running in all directions. This allows movement of the fascia in any direction and it ensures adjustments for muscular changes in any direction.

Other observations by Manheim (1994: 14) were that "fascia shrinks when inflamed", "is slow to heal because of a poor blood supply" and "is a focus of pain because of its rich nerve supply". These are factors to keep in mind when referring to muscle injuries or muscle dysfunction. If the fascia surrounding the muscle fibers "shrinks", we can assume this to have an immediate effect on the muscle and the functioning thereof. As the fascia and muscle are so intertwined, it is significant that the fascia takes long to heal, possibly longer than muscle tissue, which is seldom taken into consideration when recovering from injuries.

In summary, all movements rely on a well-distributed, non-restricted fascia throughout the body. This allows for optimal movement between adjacent and non-adjacent muscle groups (Barnes, 1990: 5). Viewing the body from this perspective, it is clear why dysfunction, tightness or inefficiency in one area of this perfectly balanced system might be caused by dysfunction in another area and will in turn affect yet another area. It also emphasizes the fact that no symptom should only be treated or rehabilitated locally, but the whole myofascial structure should be taken into consideration.

FACTORS PLAYING A ROLE IN OPTIMAL MUSCLE FUNCTIONING

Lardner (2001:257) described four systems that provide musculoskeletal stability for optimal muscle function, namely the active muscular component, the passive osteo-ligamentous component, the controlling neural component, and the passive fascial component. These four systems function together and any alterations in one system will have an effect on the other three systems. Masi and Hannon (2008: 326) recently added the passive myofascial tone or tension as a fifth system assisting in stabilizing the musculoskeletal system.

The main functions of muscles in the body are to maintain specific postures, whether static or dynamic, and to perform efficient movement with the help of input from the central nervous system. To perform these functions, each muscle must be able to lengthen and contract. Contraction of a muscle causes an expansion in the volume of the muscle. The surrounding and intertwined fascia will limit the expansion in spite of the ongoing muscle contraction, causing an increase in pressure. This pressure change will assist in transmitting forces along the myofascial network (Garfin, Tipton, Mubarak, Woo, Hargens & Akeson, 1981: 319). A loss in extensibility of a muscle will result in reduced movement efficiency. As the muscle is then no longer capable of efficient movement, other muscles must be recruited to assist with the movement. The normal coordinated movement pattern becomes altered and the overused muscle not designed for that specific movement may develop myofascial trigger points, inhibiting the function of those muscles as well (Han & Harrison, 1997: 92; Tunnell, 1998: 21). According to Valouchová and Lewit (2009: 262), connective tissue plays an important role in muscle and joint movement by moving with these structures when movement takes place. Any restrictions in the connective tissues will affect the ability of the musculoskeletal system to function efficiently.

MUSCULOSKELETAL INJURIES

Any stress on the body can be positive, as long as the body is able to tolerate the stress and utilize it to adapt and strengthen. As soon as stress becomes too much for the body, and specifically the musculoskeletal system, to tolerate, failure and eventual injury will be the result. Feldenkrais (1981: 53) believed that the causes of injury, pain and movement restrictions are mainly the result of repeated incorrect movement patterns.

Classifying injuries

Injuries can be defined as either traumatic or chronic. A traumatic injury has a sudden onset when a load or force too great for the tissues to withstand is applied, causing the tissues to fail (Wilson, 2002: 239). Chronic injuries develop over time and are not linked to one specific event. Identifying the specific causes of chronic injuries is difficult, as it is often a previous injury or other predisposing factors that decreased the threshold ability of the tissues to withstand force. Adding to this is the stress of the activities to which the person is often still subjected at the time. The muscle tissues are repeatedly predisposed to high loads in sports and can bear these loads for a certain amount of time. However, as soon as an extra load is added or repeated too often without adaptation to the previous load, or a previous injury is apparent, the tissues may fail to withstand the force. Without the predisposing factors, this specific movement would probably not have caused an injury (Wilson, 2002: 239).

Extrinsic and intrinsic causes of injuries

Renström and Johnson (1985: 316) identified the causes of muscle injuries as intrinsic factors, including malalignment and muscle imbalances, or extrinsic factors, which were mainly training-related. Giffin and Stanish (1993: 1765) reviewed related literature and identified various intrinsic and extrinsic factors as causes of overuse injuries. Intrinsic factors predisposed a structure to injury, mainly when that structure is placed under excessive or repetitive loads. Muscle imbalances were recognized as a major intrinsic factor. Extrinsic factors, such as a sudden change in training load, poor technique and high-intensity training sessions, all add to the already present intrinsic factors, but are easier to modify.

Croisier (2004: 684) conducted a literature study to identify possible intrinsic and extrinsic causes for the high frequency of recurrent hamstring injuries in athletes. The aim of the study was to suggest a protocol for rehabilitation and return to sport, in order to minimize the recurrence of hamstring injuries. He found that initial hamstring injuries resulted in deformation of the muscle tissue, formation of scar tissue, decreased flexibility or elasticity under tension and a resultant change in the biomechanics. All of these assisted in creating muscle imbalances. The intrinsic factors he found were mainly muscle imbalances and returning to sport after an injury without correcting these imbalances. Fatigue due to high-intensity training sessions was noted as an important extrinsic factor. Fatigue predisposed the athlete to injuries, as compensation took place once fatigue sets in.

According to Laker *et al.* (2008), the actions that place stress on the body, especially the musculoskeletal system, can be tension, compression and even muscle contraction. Fatigued muscles, tendons or connective tissues cause changes in the physiology of these structures. Initially the tissues adapt to the stress, but whenever the stress is too great or continuous, or insufficient recovery time is allowed, the tissues does not heal sufficiently and the next stressor placed on it causes injury.

Overuse injuries

In spite of all the advantages of taking part in organized sports, a higher level of sport participation is seen as an increased risk for injuries. Giffin and Stanish (1993: 1765) reviewed literature studies on tendon injuries and rehabilitation and found that 50% of sports injuries were overuse injuries, most of them affecting the musculoskeletal system. According to a study on overuse injuries by Pécina and Bojanić (2005: 1), 30 to 50% of all sports injuries were classified as overuse injuries. Hodson (1999: 85) described an overuse injury as an injury that develops due to repetitive activity over time and gradually worsens when this specific activity is continued. Micro-trauma on the muscles, bones, tendons and soft tissues are caused by repetitive actions. It will result in an injury if the body part can not resist the amount of trauma or did not get sufficient time to recover before the next load of microtrauma is exerted on it. The load on the body and the musculoskeletal system at midstance in running (running is used in most sports and in rugby) is 250 to 300% of a person's body weight. This emphasizes why any abnormalities, malalignments or even training errors will have a multiplied effect if the athlete performs repetitive activities (Pécina & Bojanić, 2005: 1).

In the case of repetitive activities, the muscles fatigue, decreasing the strength and precision of contractions, and increasing the risk of injuries. Wilson (2002: 241-242) reviewed various studies on musculoskeletal injuries in an attempt to develop an effective treatment plan. He found that overuse injuries could be prevented "if given sufficient intervals of rest and recovery". He suggested that any sources of unnecessary muscle tension be minimized or removed to improve recovery, such as a too high workload or repetitive actions.

MYOFASCIA AND THE MUSCULOSKELETAL SYSTEM IN THE EVENTS LEADING UP TO AN INJURY

Chaitow (2007: 27) identified a sequence of events following abnormal amounts of stress on the body, whether from repetitive actions, overuse or trauma. The sequence starts with applying increased stress on the musculoskeletal system, more than it can tolerate. In the case of a continuous stressor, changes occur in the fascia due to increased collagen production. The collagen is not formed in the same way as when adaptation occurs, but rather in an altered pattern, shortening and restricting the fascia. The fascia is then unable to adapt to more stress, and fatigue and damages easily. As a result of the continuity of fascia through the body, this initial disruption in the fascia will influence all structures the fascia is attached to and continuous with. A reactive tightening of the postural muscles and weakening of the phasic muscles throughout the body occurs.

As the person or athlete continues with daily or sporting activities, the central nervous system has to allow compensatory patterns in response to the less efficient, tighter and weaker muscles. Over time, the body will start to adapt to these compensatory patterns. When the initial movements are now repeated, the musculoskeletal system will utilize the compensatory muscle activation patterns to perform the required movement. This often results in poorer coordination or motor control of the movement and changes in the biomechanics of the movement. Another alteration appears in the sequence in which the muscles are activated during a specific movement or action. This in itself can lead to further compensations, as these movements are not biomechanically efficient anymore and will place the joints, muscles and connective tissues under constant strain. All of the above changes will result in less efficient movements that waste unnecessary energy, result in poorer performance of biomotor abilities, and eventually in more injuries. The solution would be to identify the source(s) of fascia restrictions or changes and free the fascia of these (Chaitow, 2007).

CHANGES IN THE MYOFASCIA AFTER INJURY

From the viewpoint of a manual therapist, Barnes (1997: 232) examined the physiologic changes in the tissues after trauma or injury. According to Barnes, “tightening of the fascial system is a histologic, physiologic and biomechanical protective mechanism that is a response to trauma”. Changes occur in the composition of the ground substance. It takes on a more solid form, the collagen becomes denser and the elastin component becomes less elastic. The fascia becomes restricted and is not able to absorb stress and forces on the body effectively. This will lead to an altered tensegrity structure, poor force distribution, an altered alignment and poor biomechanics, which again might lead to more injuries and poorer biomotor abilities.

Connective tissue, in this case the fascia, is viscoelastic, with elements of both viscosity and elasticity. Temporary changes occur in the elastic component when subjected to stress, while more permanent deformations occur in the viscous component. Cantu and Grodin (1992: 32) described this phenomenon. Initially, any slight force will affect the length of the connective tissue, but as more stress is applied, the changes in length become less severe. The elastic component is responsible for the initial temporary changes in length. When a tolerable amount of strain is applied on the fascia, the composition of the fascia will constantly change as the tissue strengthens to be able to adapt to the increased stress. When too much tension is applied, the viscous component starts to alter the shape of the fascia more permanently, up to a point where the fascia will not be able to tolerate the forces anymore and fail or disrupt, causing restrictions in the fascia (Cantu & Grodin, 1992: 32).

Stecco (2009: 60) noted that “the formation and maintenance of collagen in dense connective tissue is highly dependant on stress and physical stimuli, and it may be altered in pathological conditions (immobilization, trauma, overuse and surgery)”. This implies that the body requires a certain measure of stress on the connective tissue to ensure the formation of more collagen fibers to strengthen the structures and prepare the body for more stress. Under the above conditions, the formation of the connective tissue changes and it is not able to adapt to the same or an increased amount of stress.

According to LeBauer, Brtalik and Stowe (2008: 358), restrictions in the fascia are caused by "injuries, stress, inflammation, trauma and poor posture". They emphasized that all restrictions should be identified, as they place stress on the surrounding muscles, influencing efficient muscle function. Manual myofascial release therapy was suggested to release any restrictions in the fascia. Barnes (1997: 232) and DellaGrotte, Ridi, Landi and Stephens (2008: 232) noted that removing restrictions and restoring the normal length of the fascia will restore the alignment of the myofascia and allow more movement around joints. This will result in greater movement efficiency.

When a muscle is injured, whether it is a strain or a contusion, scar tissue (also a type of connective tissue) is formed, replacing the original tissue in that specific area. Scar tissue is formed between the myofibers as part of the healing process. This strengthens the injured area of the muscle in order to withstand future forces, but causes the muscle to lose some of its elasticity as full regeneration of the muscle fibers are prevented by the scar tissue formation (Järvinen *et al.*, 2007: 318-319). Reviewing several studies, Cantu and Grodin (1992: 50) noted the effects of scar tissue formation and immobilization after injuries. Both of the above changed the structure of the fascia, reducing its ability to stretch and extend when subjected to pressures. It also reduced the ability of the fascia to absorb forces and to transmit those forces through the body, implying that the previously injured area will be at a much greater risk of being re-injured. Valouchová and Lewit (2009: 266) tested 13 patients with active scar tissue on their abdominal area, and compared the function of the muscles around the scar tissue to those of 13 control subjects. They found a major asymmetry in the muscles on the side of the scar compared to those on the uninjured side in the 13 patients. After manual release treatment of the scar tissue, a significant decrease in asymmetry was noted, as well as less back pain in these patients. The conclusion was thus that the formation of scar tissue after injury contributed to muscle imbalances and muscle dysfunction.

In summary, overuse injuries will result in the protective tightening of the fascial connective tissues. In the area of the injury the fascia will become restricted, changing the distribution of the fascia through the body. Keeping the principle of tensegrity in mind, tension or strain on the fascia in one area will indirectly affect more joints and muscles, changing their normal alignment and biomechanics. Altered movement patterns, decreased coordination and decreased strength and muscle endurance will result. A proper distribution of the fascia is thus necessary for efficient muscular functioning (Barnes, 1997: 234).

THE MUSCULAR SYSTEM FUNCTIONING AS KINETIC CHAINS OR FUNCTIONAL SYSTEMS

Prentice and Voight (2001: 215) described a kinetic chain as a well coordinated articular, neuromuscular and myofascial system functioning together as one unit. The precise arrangement of each kinetic chain ensures optimal efficiency during functional movements, which occurs only if each part of the chains functions optimally. They identified the most common causes of muscle imbalances or dysfunctions in a kinetic chain as "postural stress, poor neuromuscular efficiency, pattern overload, overtraining, and poor technical efficiency".

Nadler, Malanga, Feinberg, Prybicien, Stitik and Deprince (2001: 575) noted that the body consists of linked segments functioning together as kinetic chains. They conducted a study on 163 college athletes to assess whether athletes with hip muscle imbalances had an increased chance for lower back pain. Strength tests were used to measure the difference in strength of the right and left hip extensor muscles, as well as the difference between the strength of the right and left hip abductors muscles. Occurrences of lower back pain were noted in subjects in the year following the initial tests. A significant relationship was found between muscular imbalances of the right and left hip extensor muscles in female athletes and the occurrence of lower back pain. The researchers also found that previous lower back and / or lower limb injuries led to compensation of muscle activation patterns and inhibition of the hip muscles, emphasizing the existence of kinetic chains of muscles functioning together.

Lucas *et al.* (2004) conducted a study to examine the effect of latent myofascial trigger points on muscle activation, using male and female volunteers from a group of students and staff at a university. All subjects had at least one latent myofascial trigger point in their rotator cuff muscles. Surface electromyography was used to examine muscle activation patterns of the shoulder rotator cuff muscles during elevation of the arms in the scapular plane. The researchers found that the presence of a trigger point changed the normal muscle activation patterns of the muscle with the trigger point. It also changed the activation patterns of the muscles along the kinetic chain. Trigger points were removed in one group of subjects, using dry needling and passive stretching. The muscle activation patterns all returned to normal in that group. Thus, myofascial restrictions in the form of trigger points influenced muscle function of a muscle in isolation and of muscles in a kinetic chain. This again confirmed the existence of kinetic chains functioning as one unit.

To perform movements, no muscle works in isolation, but specific muscles work together as coordinated functional systems. According to Key *et al.* (2008: 9), the muscular system works together as functional parts and these form a whole coordinated system. The authors stated that "a local pain symptom is usually an expression of a local, regional and general dysfunction of the neuromuscular system". As mentioned earlier, if one or more of the muscles in one functional system does not function properly, a muscle from another system, not designed for the exact same function, will be recruited. The timed activation of certain muscles or muscular chains related to a specific movement is then affected. An altered motor control and activation sequence of muscles can create a bigger problem than the actual strength of the muscles. Even a very strong muscle that does not contract when needed, is less efficient and does not stabilize the joint effectively during movement. Key *et al.* (2008: 11) conducted postural evaluations on several patients with lower back pain. They used these evaluations to analyze two muscular systems and to investigate the function of these two systems in their back patients. The conclusion was that local pain was the result of a muscular system dysfunction and not an isolated muscle dysfunction, as well as of imbalances in the activation and coordination of the muscular systems. The researchers also concluded that optimal movement required the correct activation and coordination of all the muscles in each system and in the whole body.

DellaGrotte *et al.* (2008: 215) noted the importance of movements occurring in neuromotor myofascial pathways. The biomechanics of the body makes it possible for movements to take place, while the tensegrity structure of the body ensures that movements are performed using a specific sequence or pathway. Along each of these myofascial pathways, the least strain and tension on the biomechanical structures are felt and movements are more energy efficient.

Recently, Stecco (2009:53) investigated myofascial continuities in the upper body. He dissected fifteen cadavers to analyze the myofascia and identify myofascial connections. The myofascial connections were based on connections of the anterior region of the shoulder and upper limb as proposed by other researchers. Clear continuations of fascial sheaths covering all the arm muscles involved in the same directional movement was found in all subjects. These connections along muscles involved in the same directional movement formed a kinetic chain. Manual traction was used to simulate the effects of myofascial expansions (muscle contractions stretching the surrounding fascia). The direction of the resultant line of force was noted and in all cases it followed the proposed myofascial chains. The conclusion was made that myofascial chains exists and any changes in muscle tension is communicated through the fascia to all the muscles in the kinetic chain.

To summarize, scientific research confirmed the existence of muscles functioning in kinetic chains. Restrictions, injuries or dysfunctions in any part of a kinetic chain does not affect the localized area only, but is transferred along the chain and can lead to compensations and dysfunction elsewhere in the chain. The muscles in the kinetic chain will react by either tightening or changing their pattern of activation to still perform movements and to protect the surrounding joint(s).

ANATOMY TRAINS – MYOFASCIAL KINETIC CHAINS

Myers (1997b, 2001, 2009) divided the whole fascial network into functional lines or kinetic chains of myofascia. Each of these kinetic chains were named and classified according to movement functions of the body they were involved in. They were called anatomy trains because of their continuity. He found that localized injuries tend to transmit tension along these lines first, leading to eventual dysfunction of the entire line. One dysfunctional line created an immediate imbalance in the myofascial network, increasing the risk for dysfunction or injuries along any of the other lines. Myers suggested that balancing of the lines and therefore of the body as a whole functioning unit would minimize the effects of previous injuries, reduces the risk for future injuries and improves overall movement function of the body (Myers, 1997b, 2001, 2009).

The following kinetic chains were identified by Myers (2001, 2009):

a. Superficial back line
b. Superficial front line
c. Deep front line
d. Lateral line
e. Superficial back arm line

Each line will be described in more detail in the following paragraphs, as a summary of the main aspects by Myers (2001, 2009).

Superficial back line

This line connects the posterior surface of the body and forms a continuous connection of myofascia from head to toe. Symmetrical lines are formed on the right and left sides of the body. The postural function of this line is to support the body in extension, preventing the often seen tendency in people to bend over or slump. It creates and maintains the cervical, thoracic and lumbar curves. To maintain this posture, the superficial back line requires slow-twitch, endurance-type muscle fibers and very strong fascial sheaths. The movement function of this line is linked to its postural function. The postural function is to initiate and create extension or hyperextension and to limit forward flexion. This line allows trunk and hip flexion with extended knees, knee flexion, plantar flexion and trunk hyperextension. It mediates movements in the sagittal plane only.

Superficial front line

This line connects the anterior surface of the body from head to toes, but is only a continuous myofascia line when the hip is extended. Right and left symmetrical lines are formed. The postural function of this line is to support the body parts extending forward of the gravity line, such as the rib cage, and to balance the superficial back line. This line also plays a role in maintaining extension of the knees when standing. The movement function of this line involves forward flexion of the trunk and hips, knee extension and dorsiflexion of the foot. The body generally needs more sudden, strong movements into flexion than into extension, therefore the muscles in the superficial front line will contain more fast-twitch fibers. The superficial front line, like the superficial back line, initiates and maintains movements in the sagittal plane.

Deep front line

The right and left deep front lines are on opposite sides of the body, also in the frontal plane. These lines are known as the "myofascial core" of the body, consisting mainly of supporting muscles and fascia. The postural function of this line is to support the head and neck on top of the spine, stabilize the chest, lumbar spine and legs. This line opposes and balances the lateral line, particularly in the legs (Myers, 2001: 217). The movement function of this line relates to its muscle fiber type, which is mostly slow-twitch, endurance-type fibers, playing a role in stabilization rather than movement. Adduction of the hip is the only movement this line performs on its own. Its main function is stabilizing the body while the other lines perform their movements. Any dysfunctions or restrictions in this line will result in poorly coordinated movement patterns in any of the other lines.

Lateral line

This line runs down both sides of the body from the side of the feet to the head and connects the deep areas of the body. The postural function of this line is to balance the right and left sides of the body and to balance the postures of the front and back. The movement function of this line is mainly involved in side to side movements in the frontal plane and prevents excessive lateral or rotational movements. Examples of movements using the one lateral line and stretching the opposing lateral line are lateral trunk flexion and leg abduction at the hip. Any restrictions in lateral movements in the frontal plane will be due to restrictions in the myofascia of the lateral lines.

Superficial back arm line

Myers (2001, 2009) identified four arm lines, a deep front of the arm line, a superficial front of the arm line, a deep back of the arm line and a superficial back of the arm line. A description of the superficial back arm line is included as this line combines with the superficial back line to form a posterior stabilizing line.

According to Myers (2001, 2009), it is important to identify any restrictions in a line, balance left and right corresponding line and lastly to balance all the lines with each other. The most important balances are the lines doing opposing work, for example the superficial back line and the superficial front line. The deep front line in-between will also influence the function of both the superficial front and back lines.

OTHER FUNCTIONAL SYSTEMS

Functional systems or kinetic chains have also been identified by other researchers. In spite of slight differences, all these systems were based on the fact that movement is organized along myofascial pathways.

Core integration pathways

Based on the works of Feldenkrais and Myers, DellaGrotte *et al.* (2008: 232) identified six functional core pathways along which the central nervous system organizes all movements and transmit forces. These myofascial-anatomical pathways relates to the Anatomy Trains of Myers (2001), in that it also runs along the kinetic chains and follows the fascia lines along which tension is spread. Muscle activation occurring in the sequences of these pathways ensures efficient movement, as it minimizes stress on the bones, joints, muscles and fascia. The pathways identified were the back path, the front path, the turning path, the diagonal spiralic path, the basic lateral path and the lateral opposite bend path (DellaGrotte *et al.*, 2008: 233).

The pathways or kinetic chains of DellaGrotte *et al.* (2008) can be explained as follows: The back and front paths support movements in the sagittal plane. The back line muscles and fascia specifically strengthens the core and all the structures along the back, while the front path enables dynamic core support during movement. The turning and diagonal spiralic paths have the same type of function, i.e. allowing twisting and turning movements. The turning path lies in the transverse plane and integrates the functions of both the back and front paths, while the diagonal spiralic pathway focuses mainly on full body movements. The basic lateral path and the lateral opposite bend path are linked and both are involved in side bending. The basic lateral path focuses more on side bending of the leg, hip and lower back, while the lateral opposite bend path focuses more on balancing and weight shifting in the transverse plane.

Aaberg's subsystems

Aaberg (2007: 75) recognized the systems of muscles moving in synergy in the human body. He emphasized that "isolated joint or muscle actions are rarely performed in real life". Muscles work together in a system, either to stabilize or perform a specific movement. Any movement performed repetitively will only recruit the same muscle groups and develop coordination in that system. It is vital that all subsystems function properly, as they are all involved in some aspects of stabilization and neuromuscular function. Five subsystems were identified that enables the body to perform all functional movements, namely the inner core, the deep longitudinal subsystem, the lateral subsystem, the posterior oblique subsystem and the anterior oblique subsystem (Aaberg, 2007: 75).

The deep longitudinal subsystem stabilizes the body from head to toe, controlling movements in the sagittal plane. The lateral subsystem assists the deep longitudinal subsystem, but also controls and initiates side-to-side movements in the frontal plane. The posterior oblique subsystem plays a role in rotational movements and assists the deep longitudinal subsystem.

This system is balanced by the anterior oblique subsystem, which is also involved in rotational movements. These subsystems all regulate the basic movements used in daily activities.

RELATIONSHIP OF THE LINES TO BIOMOTOR ABILITIES AND INJURIES

To prepare the body for performance in any sport, repetitive movement training is needed. Based on the requirements of the specific sport, certain movement patterns must be repeated more than others. The applicable kinetic chains for these movements will thus be stressed more, causing a thickening of fascia around these muscles to provide stability during the repetitive muscle actions. Over time, the increased tightness of the surrounding fascia will inhibit free and efficient movement of these muscles. This might lead to imbalances in the strength and endurance of the kinetic chains in the body (Chaitow, 2007; De Witt & Venter, 2009). In two opposing lines, for example Myers' (2001, 2009) superficial back line and superficial front line, tight, shortened muscles in the one line will results in long, stretched muscles in the opposite line. If it becomes a chronic condition, the muscles in the kinetic chain will be "locked" in these positions, thus the naming "locked-long" or "locked-short" to describe the position of the muscles in the chain (Myers, 2001, 2009). De Witt and Venter (2009: 81) assessed muscle lengths of elite athletes and found that stabilizing muscles became "locked-long" with repetitive use, while the more powerful mover muscles tend to become "locked-short" with repetitive use.

According to the principle of tensegrity, tightening or shortening of the myofascia in one area will result in lengthening of the myofascia in another area. The stability of the total structure is thus compromised (Chaitow, 2007). This has an influence on both the performance of biomotor abilities in athletes and on injury occurrence. It is therefore vital for athletes to maintain function and balance in all kinetic chains.

An area of dysfunction or pain is not necessarily the origin of the problem, as force is transmitted along the myofascial chains and does not stay localized in one area (Myers, 2004: 133). As stated above, injuries occur in an area and the resulting tension is then spread along the kinetic chain and eventually to the other kinetic chains. It is also possible that dysfunctions may occur where two lines cross, if one line already has a weak area close to the crossing. It is therefore important to identify all the restrictions among all the lines, as even only one restriction can lead to dysfunction, injury or re-injury (Myers, 1997b: 143).

POSSIBLE METHODS TO ASSESS FASCIA ALIGNMENT AND FASCIA RESTRICTIONS

Various methods have been proposed by researchers to evaluate the myofascial system and identify restrictions. These methods range from visual and palpatory methods, postural evaluations, evaluating segments of the body, evaluating muscles in their kinetic chains, to using isometric tests to test the functionality of myofascia in kinetic chains.

Visual and palpatory methods to evaluate restrictions in the myofascial system were used by a number of researchers. Both Barnes (1990: 18) and Chaitow (2007: 19) used the above, as well as functional muscle tests. Barnes (1990: 18) proposed a visual and manual palpatory evaluation of the fascial system to identify restrictions. He suggested observing the patient while standing, in a supine position, walking and while performing more functional and stability movements, in order to identify any asymmetries. Barnes then used manual palpation to identify the fascia restrictions where asymmetries were apparent. Chaitow (2007: 19) also recommended manual palpation to detect trigger points in the myofascia. He evaluated postural alignment and scapulohumeral rhythm and used basic muscle testing to assess flexibility, strength and endurance of individual muscles and groups of muscles. These tests should assist in identifying the functioning ability of the muscles, which relates directly to the presence of fascia restrictions. Furthermore, he suggested using functional tests to identify biomechanical dysfunctions, such as the hip extension test, one-legged balance test and core stability tests.

Cantu and Grodin (1992: 85) started their assessment by focusing on a specific body area. A segmental evaluation was then performed to identify abnormalities around specific joints. Kendall *et al.* (1993: 349) recommended evaluating all structures related to the proposed restricted area, instead of just evaluating and treating the area of the symptoms. His suggestion was based on the notion that all muscles function together. Myers (2001: 250), the developer of the Anatomy Trains myofascial continuities, suggested looking even wider and identifying which myofascial lines or kinetic chains showed restrictions and addressing these lines. Deppen (in Donatelli, 2007: 145) also noted the importance of evaluating kinetic chains.

The researcher examined lower body injuries in athletes and emphasized that these injuries could be the cause of dysfunction in any structure in the lower body kinetic chains. The normal muscle activation pattern of muscles in a kinetic chain was disrupted after injury, leading to overload and compensation in the same and other kinetic chains. Therefore, Deppen (in Donatelli, 2007: 145) suggested focusing on rehabilitation of each of the interdependent kinetic chains, instead of focusing on rehabilitation of an isolated muscle or joint.

In contrast to manual palpatory methods, McGill (2002: 225) used isometric testing to assess the endurance and balance of kinetic chains. He conducted an experiment using isometric tests for three kinetic chains or myofascial pathways in patients with low back pain. Test positions for the lateral musculature, the flexor musculature and the extensor musculature was used to identify muscle imbalances along these three kinetic chains. Two groups of men (mean age of 34 years) was tested on each of the above three positions. One group had no previous or current incidence of back pain, while the second group experienced back pain. The aim of McGill's (2002:227) tests was to hold each of the three positions for as long as possible. The second group showed more differences between the scores of the three tests, indicating imbalances between the three kinetic chains. McGill emphasized the importance of achieving balance in the kinetic chains, instead of only focusing on the amount of time each position could be held. The main finding of his study was that people with no back pain had balanced kinetic chains, while people with back pain had imbalances in the kinetic chains.

Donatelli (2007: 193) suggested evaluating the core strength of an athlete using manual isometric muscle tests. These are then used to determine the cause and possible treatments of injuries. Even though the researcher advised the use of isometric testing, he also noted that his tests were for muscles in isolation only, not the whole kinetic chain, and tests only isometric muscle strength, not muscle activation patterns.

Nesser *et al.* (2008: 1750) conducted a study on 29 division I college football players in order to determine the relationship between core stability and performance. Four isometric core tests were used to measure the muscle endurance of the flexor, extensor, and right and left lateral musculature or kinetic chains. These four kinetic chains are responsible for stabilizing the upper body. The aim of the tests was to hold each position for as long as possible. Three of these were the same isometric tests as suggested by McGill (2002: 225). The performance tests used in this study included two sprint tests, an agility tests, a vertical jump test and three muscle strength tests. Significant, but not strong, relationships were found between core strength and performance in these athletes. When the results of the four core tests were added together, stronger relationships were found between core strength and performance. This finding indicated that the functionality and balance of all the kinetic chains should be taken into consideration when evaluating an athlete's core strength. The researchers suggested that more testing is needed to confirm the relationship between core stability and performance in athletes.

De Witt and Venter (2009: 88) proposed the Bunkie-test as a tool to identify fascia restrictions in five functional lines or kinetic chains. This isometric test was developed over a period of 12 years by a South-African physiotherapist working with elite athletes. De Witt and Venter (2009: 82) noted that repetitive movements, as required in most sports, could cause the fascia to shorten and thicken around overused muscles and lengthen in another area of the body. This leads to imbalances, which can lead to dysfunctions or injuries. The aim of the Bunkie-test was to identify in which kinetic chains along the fascia lines restrictions are apparent. The kinetic chains used are based on Myers' Anatomy Trains (2001, 2009). Each of the kinetic chains has its own testing position and is repeated on the right and left sides of the body. The athlete is required to hold each position for 40 seconds. The researchers noted that, if the fascia is fully functional in a specific line, it should allow all the muscles in that line to activate and support the body in the test position for that line. If the athlete cannot hold the position without any discomfort, a restricted or "locked-long" area in the fascia of that line is indicated. In the Bunkie-test, there are two power lines and three stabilizing lines. The power lines are the posterior power line, relating to the superficial back line of Myers (2001), and the anterior power line, relating to the superficial front line of Myers (2001). The stabilizing lines are the lateral stabilizing line, relating to the lateral line of Myers (2001), the medial stabilizing line, relating to the deep front line of Myers (2001) and the posterior stabilizing line, relating to a combination of Myers' lines. The aim of the researchers was to introduce the Bunkie-test and to emphasize that athletes must aim towards fully balanced kinetic chains. The test should thus be repeated regularly after intervention until all positions can be held for 40 seconds.

No tests other than the Bunkie-test could be found to assess the fascia alignment of the whole body in an easy, non-invasive way. Recent interest in the Bunkie-test was also noted among physical therapists (Brumitt, 2009), using the test to assess core function along the fascia lines. Therefore, the Bunkie-test (De Witt & Venter, 2009) was chosen as a tool to test for fascia restrictions in this study.

RUGBY

Rugby is one of the most popular sports in South Africa and is played at school level, at tertiary institutions, as well as amongst the adult population at an amateur, semi-professional and professional level (Gabbett, 2003: 36; Gabbett, 2004b: 743). This sport is played second most across the world after soccer, and is still gaining popularity. 92 National Rugby Unions exists over the world (including South Africa), illustrating the popularity of this sport (Duthie, Pyne and Hooper, 2003: 974).

Rugby is a dynamic contact sport played on a grass field and involves rapid movements and changes of direction, jumps and sprints (Bompa & Claro, 2009). It requires physical strength, power, speed, agility and muscle endurance to complete the repeated spurts of high-intensity movements, alternated with lower-intensity walking or jogging. A huge amount of physical contact or tackles are executed between players during the game. A rugby game is played between two teams and divided into two 40-minute halves with a 10-minute break in-between. Each half is played continuously, except in the event of an injury (Duthie *et al*., 2003: 974).

A rugby team consists of 15 players, each in a numbered position with different requirements. The positions are as follows; 1 – loose head prop, 2 – hooker, 3 – tight head prop, 4 – left lock, 5 – right lock, 6 – left flanker, 7 – right flanker, 8 – number eight, 9 – scrumhalf, 10 – flyhalf, 11 – left wing, 12 – left centre, 13 – right centre, 14 – right wing, 15 – fullback. Players numbered 1 to 5 are known as the tight five or forwards, numbers 6 to 8 are the loose forwards and numbers 9 to 15 are the backs or backline players (Duthie *et al*., 2003: 975). The physical and physiological requirements vary according to the positions of the players. More strength is required from the generally heavier front row players to push forward in scrums, perform tackles and to gain possession of the ball. The second group, the loose forwards, requires the same skills as the forwards, but adding to this they also need to be faster, have more endurance and be able to accelerate when necessary. The backs are generally the faster, more agile players, requiring more endurance and speed, as they have to dodge and outrun the defence in order to score tries for points (Duthie *et al*., 2003: 975).

The 15 players in a team are physically active at various intensities for the full 80 minutes of a game, combining repeated sprints, accelerated changes of direction, power, muscle strength and endurance. The addition of a huge amount of contact and tackles between players to an already high-intensity game is possibly the cause of the high frequency of musculoskeletal injuries among rugby players (Gabbett, 2003: 36).

Some of the reviewed studies on rugby players are based on rugby league players and not rugby union players, but according to the definition of each (www.wikipedia.org), there are no major differences in skills required. Gabbett and Domrow (2005: 428) highlighted the main differences as the line-out that forms part of a rugby union game but not a rugby league game, as well as the number of players (only 13 players in rugby league). As the injuries in this current study are not classified according to phases in the game where they occurred, such as the line-out or scrum, the similarities between the games are enough to regard previous studies on rugby league players as applicable to this study.

INJURIES IN RUGBY

Since the transition from an amateur to a professional level in 1995, the intensity and importance of performing well in the game of rugby has increased. Unfortunately the number of injuries has also increased substantially (Garraway, Lee, Hutton, Russell & Macleod, 2000: 350).

Due to the before-mentioned skills required and the dynamic nature of rugby, the incidence of injuries is extremely high. Various studies have been done over the years to determine the cause of the high injury occurrence among rugby players. Clark *et al.* (1990: 559) found that "the likelihood that an individual adult player will sustain an injury during the season is of the order of 65%". To identify risk factors for injuries, Gerrard *et al.* (1994: 229-232) monitored 356 rugby players from New Zealand over one year. By scrutinizing questionnaires the players completed before the start of the rugby season, the researchers found that 82% of the players had at least one previous injury and 29% of them admitted that the injury influenced their training ability. 8% of the players sustained five or more injuries in the previous season and up to 11 injuries were noted in one player. Some of these were recurring injuries to the same body part. Players with chronic injuries amounted to 42%. Garraway and Macleod (1995: 1485-1487) studied the incidence of injuries among all the senior rugby clubs in Scotland. The study was conducted over one season and included 1216 players. 361 of the players sustained injuries. 26% of the injured players sustained more than one injury, increasing the total amount of injuries in one season to 584. The highest injury occurrence was found among the players aged 20 tot 24 years. Parkkari, Kujala and Kannus (2001: 988) reviewed articles on injury prevention and identified rugby as one of the higher risk sports. Lee *et al*. (2001: 412-416) studied a group of 803 rugby players from Scotland (mean age 23.9 years). They found that 423 players sustained a total of 675 injuries in one season. Gabbett (2003: 36-42) investigated the injury occurrence among 165 semi-professional rugby players over two playing seasons. A total of 2253 injuries were recorded during this time, confirming the large amount of injuries sustained by rugby players.

Research studies identified various reasons for the high injury incidence among rugby players. Clark *et al*. (1990: 559) and Gabbett (2003: 36-42) found the impact of tackling to be the biggest cause of injuries, while Gabbett (2004b: 743) also found overexertion and overuse as the main causes of injuries in another study on rugby players. McIntosh (2005: 120-139) reviewed various studies on rugby injuries. Most of these studies included the age group of 18 to 21 years. He found that acute injuries caused by tackles were the most common among rugby players. Bathgate *et al.* (2002: 267) recorded injury data of professional rugby players over six years. 90% of the injuries they noted were acute, while the remaining 10% were chronic or recurrent injuries. The researchers identified a higher volume of training and a higher level of play as the reasons for the high injury occurrence. Lee *et al*. (2001: 416) found that players attending more preseason training sessions had a higher incidence of injuries and re-injuries, probably due to their ability to perform at a higher intensity than other players. The injury risk among rugby players related more to the amount and type of training and previous injuries, rather than to the overall fitness level of each player. Gabbett (2004: 747) found that a decreased volume of training led to fewer injuries, confirming the above finding of Lee *et al*. (2001: 416). Gabbett (2004: 747) monitored injury occurrence and overall physical fitness in 220 rugby league players over a period of three years. The most significant finding of this study was the fact that a 10.6 - 15.7% reduction in training loads, whether by reducing the duration or intensity, resulted in a 39.8 - 50.0% reduction in injury occurrences (Gabbett, 2004: 743). In another study by Gabbett (2004a: 415), the incidence of injuries was documented among semi-professional rugby players in Australia. He found a significant increase of 95.4% in the amount of injuries when the volume of training was increased by 38.5%. Gabbett and Domrow (2005: 432-433) conducted a study to determine the relationship between performance and injury occurrence in a group of rugby players. A significant correlation was found between poorer performances in the 10m and 40m sprints and a higher injury occurrence. Lower scores on an aerobic fitness test also correlated to a higher injury occurrence.

Gerrard *et al*. (1994: 229-232) conducted a study on 92 female and 258 male rugby players to investigate the occurrence of injuries. Each player was asked to complete an injury questionnaire regarding injuries over the last 12 months. The researchers found that the high number of injuries at the start of a new season was largely the result of not completing rehabilitation programs and returning to the game too soon. Comparing research articles on injury risk factors in various sports, Emery (2003: 258-259) highlighted the increased risk of re-injury after a previous injury. Possible reasons found were not completing rehabilitation and the physiological changes associated with injuries, such as poorer propioception and loss of muscle strength. Lee *et al*. (2001: 412-416) and Gabbett and Domrow (2005: 432-433) confirmed that having an existing injury at the start of the season increased the risk of subsequent injuries. Parkkari, Kujala and Kannus (2001: 988) identified abnormalities of joint biomechanics or muscle weaknesses as risk factors for overuse injuries among sports persons.

In spite of the differences between rugby and football, both are high-intensity sports and require sudden changes of direction, multiple runs of various speeds, jumps and tackles. Therefore, studies on injuries and injury risk factors in football players were also reviewed as part of the current study. Knowles, Marshall, Bowling, Loomis, Millikan, Yang and Mueller (2009: 302) conducted a study on 3323 football players to determine injury risk factors. Previous injuries were one of the main risk factors. The researchers concluded that the changes in the musculoskeletal system or in a joint after an injury could be the reason for the greater risk of re-injury, particularly if the player did not complete the full rehabilitation process and returned to play too soon. The joints mostly at risk of recurring injuries were the shoulder, knee and ankle joints (Knowles *et al*., 2009: 310). The researchers suggested that injury prevention and proper rehabilitation should be further investigated.

Regarding injury occurrences among front row and backline players, most of the previous studies on rugby injuries found that the forwards had a higher incidence of injuries (Gabbett & Domrow, 2005: 432-433; Gerrard *et al*., 1994: 229-232; Targett, 1998;). Gabbett (2005: 969) conducted a comprehensive review of studies on rugby, including injuries. He found that almost all of the studies showed more injuries among front row players. One study found no significant differences when comparing playing positions and injuries (Garraway & Macleod, 1995: 1485-1487) and another study found that the hookers, wings and fullbacks were the most susceptible of the players (Clark *et al*., 1990: 559). The conclusion can thus be made that forwards generally show a higher incidence of injuries than backline players.

According to injury site, most of the previous studies on rugby injuries found the thigh, knee and ankle, followed by the shoulder to be the most frequently injured sites (Clark *et al*., 1990: 559; Gabbett, 2003: 36-42; Gabbett, 2004b: 743; Gabbett and Domrow, 2005: 432-433; Garraway & Macleod, 1995: 1485-1487; Gerrard *et al*., 1994: 229-232; McIntosh, 2005: 120-139).

Higher injury rates were noted at the start of the competitive season and after the break in the middle of the season (Clark *et al.,* 1990: 559-561; Garraway & Macleod, 1995: 1485-1487). McIntosh (2005: 120-139) confirmed this finding, based on his literature review, and added that some of the studies showed a gradual decrease as the season progressed and other showed more injuries at the start and end of the season. The rate of injuries also increased with the level at which players competed.

Due to the high injury occurrence among rugby players and the pressure on players to perform well and return to the game as soon as possible after an injury, it is vital to be able to identify weaknesses in performance or in the musculoskeletal system which might lead to injuries. No articles were found with any reference to the soft-tissue network, the fascia or the myofascia as a possible cause or predictor of sports injuries or poorer performance.

FUNCTIONAL PERFORMANCE TESTS IN RUGBY

Changes in the fitness profiles of elite and sub-elite players were also noticed after the transition to professionalism in 1995, as the demands of training and competition increased (Duthie *et al*., 2003: 974). Since then functional performance tests were frequently used to test the biomotor abilities and readiness of rugby players (Foran, 2001; Gabbett, 2002a; Gabbett, 2002b; Gore, 2000; O'Connor, 1995). It is essential that rugby players possess certain aspects of physical fitness, such as aerobic and anaerobic fitness, muscle strength, muscle endurance, power, agility and speed. The dynamic nature of rugby and the huge amount of sprints, changes of direction, acceleration and deceleration, jumps and tackles in a game renders it almost impossible for players to participate without possessing a certain level of these abilities and skills. Scrutinizing previous studies on rugby players, the most popular tests were identified and used to compile the test battery for this current study.

Gabbett (2002b: 334) examined the physiological differences between junior and senior rugby players. He conducted a battery of performance tests on a group of 159 junior and senior subelite rugby players. The test battery included a vertical jump test, various sprint tests, an Illinois agility test and a multistage fitness test. Testing was conducted in the middle of the rugby season. The researcher concluded that a definite improvement in overall physical fitness and physiological characteristics could be seen as the level of play and age increased (Gabbett, 2002b: 337).

In another study by Gabbett (2002a: 399), he examined the influence of the physiological characteristics of rugby players when teams were chosen. Sixty-six semi-professional rugby players with a mean age of 24 years participated in this study. Various performance tests for biomotor abilities were conducted, including a vertical jump test, four sprint tests, an Illinois agility test and a multi-stage fitness test. The results of the above tests were compared between players chosen for the first and second teams. Physiological characteristics were not significantly different between the players of the two teams.

Duthie *et al*. (2003: 974) collected data on rugby players, including data on the physiological characteristics of players. They found that performance tests were frequently used to evaluate the players' biomotor abilities and to predict performance. The vertical jump test, sprint tests and a multi-stage fitness test, amongst others, were suggested for rugby players.

A four-year study on 153 rugby players between the ages of 18 and 24 years was conducted by Gabbett and Domrow (2005). They used the vertical jump test to test lower body muscular power, the 10m and 40m sprint tests for speed and a multistage fitness test for an estimated VO_2max. They hypothesized that poor physical fitness, including power, speed and endurance, could lead to an increased injury rate. A significant correlation was found between a poorer performance in both sprint tests and an increased injury occurrence, as well as between poor aerobic endurance and an increased injury occurrence.

Gabbett (2005: 962) reviewed various articles on rugby league players, identifying the most common performance tests used. These included aerobic fitness tests, sprint tests (including the 10m and 40m sprint tests), repeated sprint ability tests, agility tests (including the Illinois agility) and the vertical jump test to assess lower body muscular power.

Durandt, Tee, Prim and Lambert (2006: 150) conducted research on rugby, hockey and soccer players in South Africa. The aim of their study was to determine which components of physical fitness were associated with performance in a 5m repeated sprint test. The tests conducted were the 5m repeated sprint test, the 10m and 40m sprint tests, an agility test and a pull-ups test, amongst others. They concluded that a combination of fitness components, rather than a single component, predicts performance in the repeated sprint test. These are the exact same tests as those used in this current study.

The relationship between fitness and biomotor abilities in rugby league players was studied by Gabbett, Kelly and Pezet (2007: 1126). Eighty-six players with a mean age of 22.5 years took part in this study. Players performed a vertical jump test, a 10m, 20, and 40m sprint tests, an agility test and a multistage fitness test was conducted. The researchers found a significant correlation between players achieving higher scores on the above tests and a better playing ability, defined as basic ball-passing and ball-carrying skills.

Gabbett *et al.* (2008: 174) conducted a study on forty-two rugby league players, with a mean age of 23.6 years, to determine the relationship between speed, change of direction speed and reactive agility. Players completed a 5m, 10m and 20m sprint test, three agility tests and a reactive agility test. A significant relationship was found between the results of the reactive agility test and times on the 10m and 20m sprint tests, as well as the change of direction speed test. This study emphasized the importance of sprint and agility tests among rugby players.

A battery of tests was used by Baker and Newton (2008: 153) to determine the differences in performance test results between rugby players participating at different levels. Twenty professional elite rugby players and twenty semi-professional rugby players participated in this study. The participants were between the ages of 22 and 25 years. The chosen tests were the one-repetition maximum squat test for lower body strength, a plyometric power test, 10m and 40m sprint tests for speed and an agility test. No differences were found between the 10m sprint, 40m sprint or agility test scores of players competing at different levels. In spite of this, these tests are still recommended and considered as standard performance tests among rugby players.

Agility

The skill termed agility consists of many aspects, such as starting a movement quickly, moving in the correct direction, stopping quickly, changing direction rapidly, quick side-to-side movements (for example to side-step another player) and sudden upwards movements (for example jumping). Rugby requires movements in a multitude of directions at varying speeds; therefore agility is an essential skill for rugby players (Foran, 2001: 6). The players possessing these abilities and using them efficiently will be able to perform better in this sport and will be able to avoid some injuries, as they are quicker in side-stepping an opponent or reacting to outside stimuli (Foran, 2001: 140-141). An agility test is designed to measure the player's ability to change direction while moving at a fast speed. The Illinois agility test is considered a standard agility test (Sheppard & Young, 2006: 927) and is used to measure multidirectional speed, agility and body control. According to Foran (2001: 315), a poor score on the Illinois agility test relates to poor leg and core strength.

Speed

Speed is a necessary skill in rugby for a front row and backline player, even though the backs are generally the faster players (Duthie *et al*., 2003: 982). Speed provides the player with the ability to get past his opponent, outrun his opponent and score points. The more speed a player has, the better his agility will be (Gabbett *et al*., 2008: 174). Depending on the position of the player, the need for speed varies. Speed tests assess the ability of the player to cover a certain distance in the shortest possible time. The 10m and 40m sprint tests are often used among rugby players as they simulate the distances covered in a game. Players almost never travel more than 40m at a very fast pace and most of the sprinting movements are no more than 10m at a time.

Speed endurance

A good aerobic capacity is a requirement for all longer duration sports. For rugby, the aerobic capacity requirements vary. Most team sports require repeated maximal or near maximal sprints of 1-7 seconds during a game that lasts anything from 60-90 minutes (Bishop, Spencer, Duffield & Lawrence, 2001: 19). A rugby match of 80 minutes with one 10-minute break is played at a high intensity and requires several repeated maximal sprints with recovery periods in-between. Therefore, a repeated sprint test is regarded as an excellent measurement of endurance or fitness for this particular sport (Duthie *et al*., 2003: 978). Various repeated sprint tests exist, but according to Bishop *et al.* (2001: 20), "virtually any repeated sprint ability test would discriminate between individuals with high or low repeated sprint ability". Rugby players with poor scores on a repeated sprint test have a poorer ability to accelerate to a maximum speed in a short time and to sprint maximally with each repetitive sprint required in a game. Players with good scores in the repeated sprint test will be able to do the opposite, i.e.

sprint maximally whenever necessary throughout the 80-minutes of the game and reach a maximal speed in a very short duration.

Explosive Power

Rugby is a dynamic, multi-directional contact sport and requires great power from all players. The Sergeant's test is the traditional vertical jump test and is often included in test batteries to measure lower limb power in the vertical direction (Aragón-Vargas, 2000: 216). This is a functional test, demands a high power output in a short amount of time, and is affected by gravity, all of which simulates the game situation. Similar movements are used in rugby in the line-outs, jumping for the ball when kicked, and in various other movements during the game. The upper body also plays a role in achieving a good score in this test (Foran, 2001: 43). Generally, the backs and loose forwards produce better scores in explosive power tests such as the vertical jump (Duthie *et al*., 2003: 981).

Upper body muscle endurance

Muscular endurance refers to the ability of an individual to perform a repeated movement using the same muscles or muscle groups (Foran, 2001: 9). Rugby players require upper body muscle endurance when repeatedly handling and throwing the ball, when pushing forward in scrums, in tackles and when trying to steal the ball from their opponents. A maximal pull-up test can be used to measure upper body muscular endurance.

CHAPTER THREE
METHODOLOGY

STUDY DESIGN

This was a prospective, descriptive and exploratory study aimed at determining the relationship between the fascia alignment (using the Bunkie-test) and biomotor abilities (using functional performance tests) in rugby players. The relationship between fascia alignment and injury occurrence (using an injury Questionnaire) was also determined. All subjects participated in a once-off assessment, consisting of several tests, and no intervention was applied.

SUBJECTS

Rugby players were chosen to be participants in this study due to the physical nature of the sport, the various movement patterns and biomotor abilities required, and the high incidence of injuries. The participants were all part of one of three rugby academies in the Western-Cape, South Africa. These three academies were selected because all their players participated at an elite level for their age group and were approximately the same age (18-21years). An appointment was made with the contact person from each academy to explain the study and all three the academies granted written permission. Each of the academies received relevant information on what the study entailed and what was required of their players.

A total of 121 rugby players consented to participate in this study, of which 59 players were registered at the Western Province Rugby Institute in Stellenbosch, 31 players at the Stellenbosch Rugby Academy and 31 players at the Rugby Performance Centre in Riebeeck-West. Grouped according to playing positions, 18 players were props, 11 were hookers, 13 locks, 23 loose forwards, 8 scrumhalves, 5 flyhalves, 19 centres, 14 wings and 10 fullbacks.

INCLUSION AND EXCLUSION CRITERIA

Only players older than 18 years and members of one of the three academies mentioned could participate. All participants had to follow their regular training programs and played competitively around the time of testing. Participants with traumatic injuries or any other injuries causing them not to be able to perform or complete the tests were excluded from this study. Minor or chronic injuries not interfering with their ability to perform the tests did not exclude such players.

INFORMED CONSENT

Each player received an informed consent form with a clear explanation of the study, including the tests, risks and benefits involved. The participants were granted enough time to ask questions before testing was conducted. All participants agreed to partake in this study by granting written permission. The Ethics Committee of the University of Stellenbosch approved all experimental procedures (Reference no: 176/2009).

QUESTIONNAIRES

Injury questionnaires were given to participants to complete in the same week as the performance tests. Each questionnaire consisted of personal information, age, playing position, at what age they started playing rugby, any operations they have had and all current injuries. The Orchard Sports Injury Classification System (OSICS), Version 10, was used in this study to classify injuries. This system was designed for rugby injuries in 1992, but can also be used for other sports. The aim was to clarify the variety of injuries when used in research studies. Four characters are used to classify an injury. The first letter represents the anatomical site of the injury, the second letter identifies the pathology, while the third and fourth letter further describes the pathology. For the purpose of this study, only the first character indicating the site of the injury was used (Rae & Orchard, 2007: 2).

Table 3.1: Orchard Sports Injury Classification System (Rae and Orchard, 2007)

Orchard Sports Injury Classification System (OSICS)	
Site of injury	Character used
Head	H
Neck	N
Chest	C
Abdomen	O
Thoracic Spine	D
Lumbar Spine	L
Shoulder	S
Upper arm	U
Elbow	E
Forearm	R
Wrist	W
Hand	P
Buttock	B
Groin / Hip	G
Thigh	T
Knee	K
Lower leg	Q
Ankle / Heel	A
Foot	F

PROCEDURES

The rugby season for players at the three academies runs from January to October. All testing was conducted during the competitive phase of the season, ensuring the players had obtained an adequate degree of match fitness. Each academy was tested over a period of one week during the month of June or July. Tests were chosen specifically to assess the fascia alignment, as well as selected biomotor abilities.

The tests included in this study were as follows:

- Bunkie-test (fascia alignment)
- Illinois agility test (agility)
- 10m sprint test (speed)
- 40m sprint test (speed)
- Repeated sprint test (speed endurance)
- Vertical jump test (explosive leg power)
- Wide grip maximal pull-up test (upper body muscle endurance)

All of the participants were familiar with the performance tests, while the Bunkie-test was unfamiliar to the participants. The majority of the participants had never seen the Bunkie-test and none of the participants has done this test before. It could therefore be assumed that none of the participants could prepare for this test in any way possible. All three academies were in the middle of their rugby season and could not stop their training for a week of testing, thus all three academies continued with their normal training sessions around the time of testing. All tests were performed in the mornings between 8h30am and 11am and the protocol used was the same for all three academies.

Tests were performed in the following order:
Day 1: Vertical jump test / Repeated Sprint test (10-15 minutes rest in-between)
Day 2: Illinois agility test / 10m and 40m sprint tests (10-15 minutes rest in-between)
Day 3: Pull-up test / Bunkie-test (10-15 minutes rest in-between)

TEST ADMINISTRATORS

Each academy had one test administrator. This person was also in charge of performance training and testing at each academy. Because they conducted tests throughout the year, they were familiar with the protocols and procedures of such tests. All of the administrators had at least two degrees from a university in a sports performance-related field and were familiar with the tests in this current study. The researcher was present at all tests.

TESTS AND MEASUREMENTS

Illinois agility test

The test protocol included a warm-up of 10 minutes, consisting of jogging forwards, backwards, sideways and doing walking lunges and squats. The agility test was conducted indoors on a hard surface with all participants wearing training shoes. The course was set up as indicated in Figure 3.1. The same measurements as those of the original Illinois agility test were used. These were also used by Sheppard and Young (2006: 927). When ready, the participant started the test and time was measured with a stopwatch until the participant crossed the finish line. The goal was to finish the indicated route as fast as possible without touching or skipping any of the cones. Two trials were recorded with a resting period of approximately 5 minutes in-between. The fastest time was recorded. Gabbett (2002b: 335) found the test-retest reliability to be 0.86 and the technical error of measurement to be 2.02%.

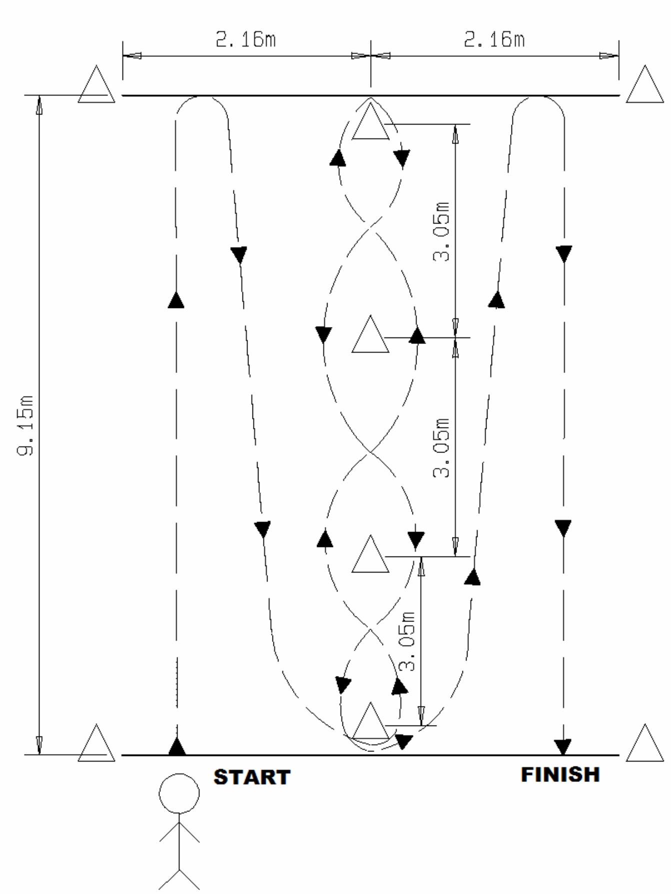

Figure 3.1 Illustration of the layout for the Illinois agility test (Reiman & Manske, 2009: 199)

10m and 40m sprint tests

In all three of the academies, the Illinois agility test was performed before the sprint tests, with a resting period of at 10-15 minutes in-between. The players warmed up before the agility test and only performed a few strides (acceleration sprints) before their sprint tests. The Swift Speed light system was set up at the start, at the 10m and 40m positions and measured both the 10m and 40m sprinting times electronically in one trial. Speed tests were conducted on an outdoor athletic track. The three-point stance (two feet and one hand touching the ground) was used as a starting position and maximal sprinting was required for the full 40m. Two trials were performed with 5 minutes rest in-between. Running / training shoes were worn. The fastest 10m and 40m of each participant were recorded. Baker and Newton (2008: 155) found the intra-trial reliability factor to be r = 0.86 for the 10m sprint and r = 0.98 for the 40m sprint. Gabbett (2002b: 335) found the test-retest reliability to be 0.88 for the 10m sprint and 0.92 for the 40m sprint. The technical error of measurement was 2.07% for the 10m sprint and 1.25% for the 40m sprint. A 90% confidence level was calculated by Durandt, Evans, Revington, Temple-Jones and Lamberts (2007: 75).

Repeated sprint test

The 5-m multiple shuttle run test for repeated sprint ability was originally used by the Welsh Rugby Union and was modified by the Sports Science Institute of South Africa. The modified version was used in this current study. The test had to be performed maximally to render the most accurate results (Boddington, Lambert, Gibson & Noakes, 2001: 224). The group of participants warmed up actively for 10 minutes before the test, performing forward, backward and sideways jogging and walking lunges. Only one trial was conducted for each of the participants. The Repeated Sprint test was conducted indoors on a hard surface. Beacons were placed 5m apart as indicated in Figure 3.2. After the test conductor indicated the start with the blow of a whistle, participants sprinted 5m towards the second beacon. Touching the ground was not compulsory in this test, but their feet had to be in line with the beacon before they could turn around and sprint back to the starting position. Without stopping, participants sprinted to the third beacon, back to the start, to the fourth beacon, back to the start, etc. until 30 seconds has elapsed. Time was recorded with a stopwatch. Participants were allowed a 35-second rest period in which they had to walk back to the starting position and wait for the next 30 seconds of sprints to commence. The 30-second-sprints were performed six times. The distance covered during each of the six 30-second-sprints was recorded to the nearest 2.5m and added together for the total distance, which was the final score for this test (Boddington *et* *al*., 2001: 224). Reliability for the 5-m shuttle test measuring repeated sprint ability is high at R = 0.98 (Boddington *et al*., 2001: 227). A 90% confidence level was calculated (Durandt *et al*., 2007: 75). Reiman and Manske (2009: 199) found no known reliability of validity for this test.

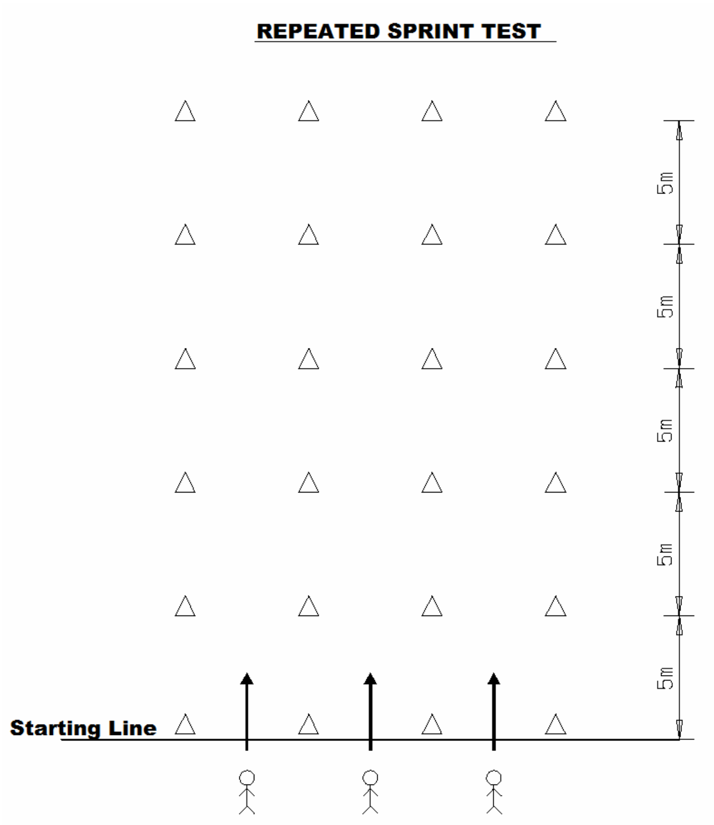

Figure 3.2 Illustration of the layout for the Repeated Sprint test (adapted from Boddington, Lambert, Gibson & Noakes, 2001: 224)

Vertical jump test

A warm-up consisting of stability push-ups, deep squats, side-to-side squats, crunches, supermans, one-leg toe touches, core activation exercises and star jumps was done before the test and totaled 10 minutes. A hard, non-slip indoor surface was used for this test. A measuring tape was mounted on the wall with the 0-mark at floor level. Each participant started with their weight evenly distributed on both feet and shoulder-width apart. They were instructed to dip their fingers in chalk and reach as high as possible on the wall with their dominant arm closest to the wall. The reaching height was recorded. Hands had to be at the participants' side before jumping and the arms could only assist with the jump itself. Participants were not allowed to move their feet prior to the jump. They were instructed to dip their fingers in chalk again, bend their knees without moving their feet and jump as high as possible, touching the wall at the highest possible mark. All participants performed this test without shoes. Two trials were recorded with 30-60 seconds rest in-between. The final score recorded was the distance between the reaching height and the better of the two jumping heights, i.e. the actual height the participant could jump. Reiman and Manske (2009: 151) documented the reliability to be equal to ICC = 0.96 and CV = 3.0%. Gabbett (2002b: 335) found the test-retest reliability to be 0.93 and the technical error of measurement to be 4.54%. A reliability and objectivity of 0.93 each was also measured for this test (Aragón-Vargas, 2000: 216).

Maximum pull-ups test

A standard pull-up bar was used for this test. Each participant started the test by gripping the bar in an overhand grip, palms facing away from the face, and straight arms. The goal was to pull the body upwards until the chin was over the bar and then return to the starting position. The total number of pull-ups the participant could perform correctly before fatigue set in, irrespective of the time frame, was recorded. The participants were allowed to cross their legs and bend their knees, but no swinging of the body to create momentum was allowed. Reiman and Manske (2009: 243) found no reliability or validity data for this test.

The Bunkie-test

The Bunkie-test is comprised of five positions or functional lines, each performed on the left and right side of the body, totaling ten positions. Each position of the Bunkie-test was performed with feet on a small bench (25-30cm high) and arms on a non-slip mat. The test was performed with training shoes to prevent slipping. All ten positions were demonstrated once and time was allowed for questions. Participants were instructed to hold each position for 40 seconds, which is the duration required for elite athletes. Timing was done using a stopwatch. The aim of the test was explained to all participants. It was emphasized that the aim was not to measure strength, but rather to identify fascia restrictions in a specific line, therefore the participants had to stop the test (each position separately) if they felt any cramping, burning or pain while holding a position. These symptoms indicated that the fascia in that specific line was “locked-long”, causing restrictions in the fascia and malalignments of the myofascia. The duration that the participant could hold each position without symptoms was recorded.

The Bunkie-test positions were performed in the following order:

1. Posterior power line

The position in Figure 3.3 indicates the test for the right posterior power line. The test was repeated with the right leg lifted off the bench to test the left posterior power line.

Figure 3.3 The position for testing the right posterior power line on the Bunkie-test

Players were instructed to do the following:

- Maintain a straight line with the body (shoulders and hips in line)
- Hold the elbows directly below the shoulders
- Hold the position without rotating the body
- Do not support with the hands under the hips
- Hold feet still with toes facing up
- Hold position for 40 seconds, unless cramping or burning is felt in any area of the body.

2. Anterior power line

Figure 3.4 indicates the testing position for the right anterior power line. The test was repeated with the right leg lifted to test the left anterior power line.

Figure 3.4 The position for testing the right anterior power line on the Bunkie-test

Players were instructed to do the following:

- Maintain a straight line with the body (shoulders and hips in line)
- Hold the elbows directly below the shoulders
- Hold the position without rotating the body
- Keep both forearms facing straight forward
- Hold position for 40 seconds, unless cramping or burning is felt in any area of the body.

3. Posterior stabilizing line

The test position for the right posterior stabilizing line is indicated in Figure 3.5. The left posterior stabilizing line was tested by lifting the right leg off the bench.

Figure 3.5 The position for testing the right posterior stabilizing line on the Bunkie-test

Players were instructed to do the following:

- Keep the shoulders and hips in line
- Hold the elbows directly below the shoulders
- Maintain a 90^{o} angle at the knees
- Hold the position without rotating the body
- Do not support with the hands under the hips
- Hold feet still with toes facing up
- Hold position for 40 seconds, unless cramping or burning is felt in any area of the body.

4. Lateral stabilizing line

The position to test the right lateral stabilizing line is indicated in Figure 3.6. The test was repeated with the left arm on the mat and the left leg on the bench to test the left lateral stabilizing line.

Figure 3.6 The position for testing the right lateral stabilizing line on the Bunkie-test

Players were instructed to do the following:

- Maintain a straight line (shoulders and hips in line)
- Hold the elbow on the floor directly below the shoulders
- Hold the other arm on the hip
- Hold the position without rotating or tilting the body
- Hold both legs straight
- Hold feet still with toes facing forward
- Hold position for 40 seconds, unless cramping or burning is felt in any area of the body.

5. Medial stabilizing line

Figure 3.7 indicates the test position for the right medial stabilizing line. The test was the repeated with the right arm on the mat and the left leg on the bench to test the left medial stabilizing line.

Figure 3.7 The position for testing the right medial stabilizing line on the Bunkie-test

Players were instructed to do the following:

- Maintain a straight line (shoulders and hips in line)
- Hold the elbow on the floor directly below the shoulders
- Hold the other arm on the hip
- Hold the position without rotating or tilting the body
- Hold both legs straight
- Maintain the position of the lower foot against the bench
- Hold feet still with toes facing forward
- Hold position for 40 seconds, unless cramping or burning is felt in any area of the body.

Reliability and validity of the Bunkie-test has not been assessed yet, even though the test was and is still used by athletes (Brumitt, 2009; De Witt & Venter, 2009). In an attempt to assess the reliability of the Bunkie-test, the researcher conducted a small test-retest experiment, using five male subjects. The participants were asked to participate and agreed to. The Bunkie-test was explained and demonstrated to them. The test protocol was the same as in the current study. Each of the participants performed the Bunkie-test four times; twice on day one, with four hours in-between trials, once on day three and once on day five. The first trial on day one and the trials on days three and five were at the same time of the day. No interventions were applied. No significant differences were found between the results of the four separate Bunkie-tests in any of the five subjects.

STATISTICAL ANALYSIS

Descriptive statistics were reported using means and standard deviations for continuous measurements, and counts and percentages for categorical variables. For comparison of continuous measurements between groups (for example forwards vs. backs), one-way ANOVA was used. The effects of injuries on the measurements were investigated using main effects ANOVA to control for the effect of forwards and backs. Categorical variables were compared using cross tabulation and the Chi-square test. Continuous variables were compared using Spearman correlations. The significance level was set at $p < 0.05$.

CHAPTER FOUR

RESULTS

SUBJECTS

The participants in this study were 121 rugby players chosen from three rugby academies. The average age of the players was 19 years. Players with acute injuries, illnesses or other prior engagements decreased the sample size to slightly less than expected. Due to minor injuries preventing participation in some lines of the Bunkie-test and some of the performance tests, all 121 players did not participate in all tests. All subjects followed the same type of training programs throughout the year and participated at the same level. The means and standard deviations of the physical characteristics of the participants are presented in Table 4.1.

Due to the physical differences between front row and backline players, their characteristics are also presented separately in the same table. The distribution of front row and backline players in the sample group was n = 65 (54%) and n = 56 (46%) respectively.

Table 4.1: Physical characteristics of participants

Characteristics	**Whole group (n = 121)**			**Front row players (n = 65)**			**Backline players (n = 56)**		
	Mean	**±**	**SD**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**
Age (years)	19.28	±	1.02	19.34	±	1.15	19.20	±	0.87
Height (m)	1.81	±	0.08	1.83	±	0.07	1.76	±	0.06
Weight (kg)	88.7	±	14.10	96.4	±	12.88	76.5	±	8.06

The number of participants in the sample group representing each playing position is presented in Table 4.2.

Table 4.2: Number of players in each playing position

Front row players	**n**	**Backline players**	**n**
Props	18 (15%)	Scrumhalves	8 (7%)
Hookers	11 (9%)	Flyhalves	5 (4%)
Locks	13 (11%)	Centres	19 (16%)
Loose forwards	23 (19%)	Wings	14 (12%)
		Fullbacks	10 (8%)

Percentages might not add up to 100% due to rounding off.

All participants were asked to fill in an injury questionnaire with their current injuries, perform the Bunkie-test, as well as six standard functional performance tests.

THE BUNKIE-TEST

The requirement was to hold each of the ten positions for 40 seconds and scores were measured in seconds. The mean score and standard deviation for each of the positions is presented in Table 4.3. The mean score on both the posterior and medial stabilizing lines were slightly lower than mean scores on the other lines, indicating that these were the positions participants struggled to perform.

Table 4.3: Mean and standard deviation for each functional line of the Bunkie-test

Functional line	Mean ± SD (seconds)
Posterior power line (right)	32.8 ± 10.98
Posterior power line (left)	32.3 ± 11.58
Anterior power line (right)	37.6 ± 7.00
Anterior power line (left)	35.7 ± 8.86
Posterior stabilizing line (right)	27.6 ± 13.64
Posterior stabilizing line (left)	25.7 ± 13.65
Lateral stabilizing line (right)	34.0 ± 9.93
Lateral stabilizing line (left)	33.9 ± 10.85
Medial stabilizing line (right)	25.5 ± 12.05
Medial stabilizing line (left)	26.0 ± 12.87

For the purpose of statistically analyzing the ten positions of the Bunkie-test, all participants were grouped according to whether they could hold the position for the required 40 seconds (the result was 'yes'), or for anything less than 40 seconds (the result was 'no'). Table 4.4 presents the number of participants in each group. The general trend showed that more participants were able to hold the required positions for 40 seconds on the power lines, but for less than 40 seconds on the posterior and medial stabilizing lines.

Table 4.4: Participants able to hold the positions of the Bunkie-test for 40 seconds compared to participants not able to hold the position for 40 seconds

Functional line of the Bunkie-test	**= 40 seconds**	**< 40 seconds**
Posterior power line (right)	60%	38%
Posterior power line (left)	60%	38%
Anterior power line (right)	83%	15%
Anterior power line (left)	73%	25%
Posterior stabilizing line (right)	42% *	56% *
Posterior stabilizing line (left)	36% *	62% *
Lateral stabilizing line (right)	62%	36%
Lateral stabilizing line (left)	66%	32%
Medial stabilizing line (right)	26% *	72% *
Medial stabilizing line (left)	32% *	66% *

Percentages might not add up to 100% due to rounding off.

* More participants not able to hold position for 40 seconds

The mean scores of the front row and backline players were compared to determine the relationship between the performances of these two groups on the Bunkie-test. Backline players performed significantly better ($p < 0.05$) on both of the posterior power lines, on the right anterior power line and on both of the medial stabilizing lines of the Bunkie-test. These results are presented in Table 4.5.

Table 4.5: Relationship between front row and backline players for the functional lines of the Bunkie-test

Variable (measured in seconds)	**Front row players Mean ± SD (n = 51)**	**Backline players Mean ± SD (n = 45)**	**p-value**
Posterior power line (right)	29.27 ± 12.37	36.71 ± 7.61	p < 0.01*
Posterior power line (left)	29.02 ± 12.46	35.76 ± 9.50	p = 0.01*
Anterior power line (right)	35.63 ± 9.21	39.87 ± 0.66	p < 0.01*
Anterior power line (left)	33.94 ± 10.15	37.62 ± 6.82	p = 0.05
Posterior stabilizing line (right)	25.20 ± 14.24	30.73 ± 12.33	p = 0.05
Posterior stabilizing line (left)	23.71 ± 13.48	27.96 ± 13.77	p = 0.22
Lateral stabilizing line (right)	32.65 ± 11.22	35.33 ± 8.22	p = 0.16
Lateral stabilizing line (left)	32.37 ± 12.36	35.47 ± 8.78	p = 0.19
Medial stabilizing line (right)	21.55 ± 12.58	29.69 ± 9.97	p < 0.01*
Medial stabilizing line (left)	21.51 ± 12.56	30.76 ± 11.46	p < 0.01*

* p < 0.05.

PERFORMANCE TESTS FOR BIOMOTOR ABILITIES

Participants were asked to perform six standard functional performance tests in order to assess biomotor abilities required in rugby. The results of the test indicated the skill level of each participant according to norms applicable for their level of competition. The test battery included an Illinois agility test for agility, a 10m- and 40m-sprint test for speed, a repeated sprint test for speed endurance, a vertical jump test for explosive power and a pull-up test for upper body endurance. The means and standard deviation for each test is presented in Table 4.6.

Table 4.6: Mean and standard deviation for each of the performance tests

Performance test	Mean ± SD
Illinois agility (seconds)	15.6 ± 0.94
10m sprint (seconds)	1.9 ± 0.12
40m sprint (seconds)	5.5 ± 0.31
Repeated sprint (meters)	728.5 ± 43.58
Vertical jump (centimeters)	53.1 ± 6.90
Pull-ups (number of)	13.0 ± 8.35

The relationship between the scores for the front row and backline players was determined for each of the six performance tests. The backline players performed significantly better ($p < 0.05$) in all the performance tests. These values are illustrated in Table 4.7.

Table 4.7: Relationship between front row and backline players for the performance tests

Performance test	Front row players Mean ± SD	Backline players Mean ± SD	p-value
Illinois agility (sec)	15.97 ± 0.97 (n = 47)	15.27 ± 0.88 (n = 40)	p < 0.01*
10m sprint (sec)	1.91 ± 0.13 (n = 48)	1.82 ± 0.08 (n = 40)	p < 0.01*
40m sprint (sec)	5.68 ± 0.33 (n = 48)	5.33 ± 0.18 (n = 40)	p < 0.01*
Repeated sprint (m)	720.53 ± 46.37 (n = 47)	745.00 ± 36.20 (n = 39)	p = 0.01*
Vertical jump (cm)	50.77 ± 7.27 (n = 47)	54.86 ± 5.56 (n = 37)	p = 0.01*
Pull-ups (number of)	9.08 ± 6.16 (n = 49)	17.49 ± 8.60 (n = 43)	p < 0.01*

* $p < 0.05$.

INJURIES

All injuries noted in the questionnaires were classified according to the Orchard Sports Injury Classification System (OSICS) of Rae and Orchard (2007). This system consists of assigning a character to each injury site. Differences in severity and types of injuries were not taken into account in this study, just the presence of an injury at a specific site. The injury sites and percentages according to OSICS (Rae & Orchard, 2007) are presented in Table 4.8.

Table 4.8: Most common injuries according to the Orchard Sports Injury Classification System (Rae and Orchard, 2007)

Orchard Sports Injury Classification System (OSICS)		
Site of injury	Character used	Percentage of players with injury
Head	H	
Neck	N	
Chest	C	
Abdomen	O	
Thoracic Spine	D	
Lumbar Spine	L	12%
Shoulder	S	27%
Upper arm	U	
Elbow	E	
Forearm	R	
Wrist	W	
Hand	P	
Buttock	B	
Groin / Hip	G	
Thigh	T	
Knee	K	28%
Lower leg	Q	
Ankle / Heel	A	26%
Foot	F	

The four most common injury sites among the players were as follows: knees (28%), shoulders (27%), ankles/heels (26%) and lumbar spine (12%). Divided further into left and right injury sites, the percentages were as follows: left shoulder (16%), right ankle (16%), left knee (15%), right knee (13%), lower back (12%), right shoulder (11%) and left ankle (10%). These are presented in Figure 4.1. Injuries with a 7% or lower occurrence rate were not presented in Figure 4.1 or used in the statistical analysis due to a too small sample size.

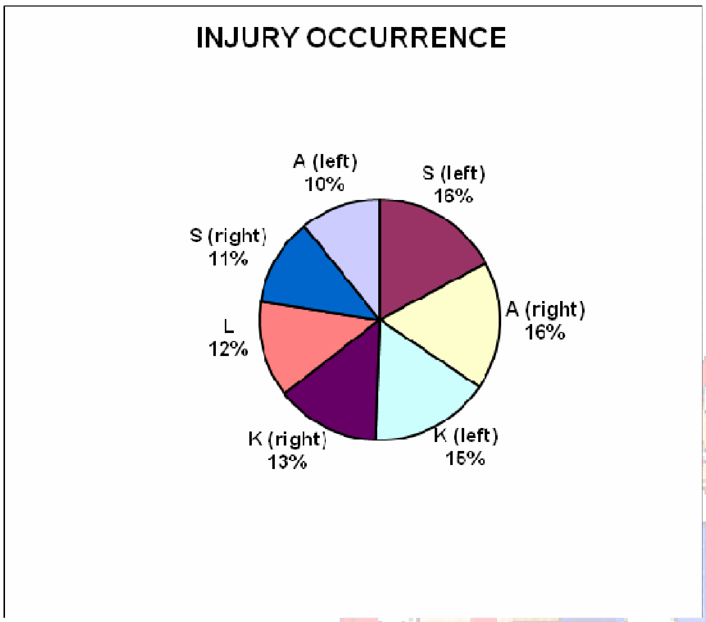

Figure 4.1: Injury occurrence according to injury site

The occurrence rate of each of the seven injuries is presented in Table 4.9. The percentages for the whole sample group, the front row players and the backline players are given. No significant differences in injury occurrence among front row and backline players were found ($p > 0.05$). A slight tendency towards more injuries among the front row players for left and right shoulder injuries was evident.

Table 4.9: Injury occurrence rate in percentage

Injury site	**Whole group (n = 121)**	**Front row players (n = 65)**	**Backline players (n = 56)**	**p-value**
Left shoulder (S)	19 (16%)	13 (20%)	6 (11%)	p = 0.16
Right ankle (A)	19 (16%)	11 (17%)	8 (14%)	p = 0.69
Left knee (K)	18 (15%)	9 (14%)	9 (16%)	p = 0.73
Right knee (K)	16 (13%)	7 (11%)	9 (16%)	p = 0.39
Lower back (L)	15 (12%)	9 (14%)	6 (11%)	p = 0.60
Right shoulder (S)	14 (11%)	10 (15%)	4 (7%)	p = 0.15
Left ankle (A)	12 (10%)	8 (12%)	4 (7%)	p = 0.34

RELATIONSHIP BETWEEN PERFORMANCES ON THE BUNKIE-TEST AND BIOMOTOR ABILITIES

If the participants' ability to perform well on the Bunkie-test lines influences biomotor abilities and performance, those participants who performed poorer on the Bunkie-test lines (i.e. < 40 seconds) are expected to also have poorer biomotor abilities, as tested with the performance tests. The relationships between performances on each of the ten functional lines of the Bunkie-test and results of all the performance tests were determined using ANOVA. These results are presented in Tables 4.10 – 4.19.

Posterior power lines

When comparing the results of the 40m sprint test, significant differences ($p < 0.05$) were found between participants able to hold the posterior power lines of the Bunkie-test for 40 seconds and those participants not able to hold this line for 40 seconds. Participants who were able to hold the right posterior power line position for the full 40 seconds performed significantly better ($p < 0.05$) in the repeated sprint test. These results are presented in Tables 4.10 and 4.11.

Table 4.10: The relationship between the mean score of the right posterior power line and results of the performance tests

	Right posterior power line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.90 ± 1.20	35	15.48 ± 0.78	52	p = 0.05
10m sprint (sec)	1.90 ± 0.14	35	1.85 ± 0.11	53	p = 0.07
40m sprint (sec)	5.64 ± 0.41	35	5.43 ± 0.22	53	p < 0.01*
Repeated sprint (m)	717.86 ± 52.81	35	741.08 ± 33.31	51	p = 0.01*
Vertical jump (cm)	50.88 ± 7.78	34	53.72 ± 5.95	50	p = 0.06
Pull-ups (number of)	11.43 ± 9.17	37	14.07 ± 7.89	55	p = 0.14

* p < 0.05.

Table 4.11: The relationship between the mean score of the left posterior power line and results of the performance tests

	Left posterior power line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.83 ± 1.08	34	15.53 ± 0.92	53	p = 0.16
10m sprint (sec)	1.90 ± 0.10	34	1.86 ± 0.13	54	p = 0.13
40m sprint (sec)	5.63 ± 0.31	34	5.45 ± 0.31	54	p = 0.01*
Repeated sprint (m)	726.36 ± 47.91	33	734.91 ± 40.79	53	p = 0.38
Vertical jump (cm)	51.26 ± 6.69	34	53.46 ± 6.88	50	p = 0.15
Pull-ups (number of)	11.36 ± 8.82	36	14.07 ± 8.16	56	p = 0.14

* p < 0.05.

Anterior power lines

Significant differences ($p < 0.05$) were found in all the performance test results among those participants able to hold both anterior power lines for 40 seconds and those not able to hold the full 40 seconds. Tables 4.12 and 4.13 present these results for the right and left anterior power line respectively.

Table 4.12: The relationship between the mean score of the right anterior power line and results of the performance tests

	Right anterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.70 ± 0.98	12	15.48 ± 0.89	75	p < 0.01*
10m sprint (sec)	1.95 ± 0.16	12	1.86 ± 0.11	76	p = 0.01*
40m sprint (sec)	5.88 ± 0.44	12	5.46 ± 0.26	76	p < 0.01*
Repeated sprint (m)	684.29 ± 53.06	14	740.83 ± 35.09	72	p < 0.01*
Vertical jump (cm)	47.15 ± 7.68	13	53.56 ± 6.25	71	p < 0.01*
Pull-ups (number of)	4.43 ± 3.69	14	14.56 ± 8.18	78	p < 0.01*

* p < 0.05.

Table 4.13: The relationship between the mean score of the left anterior power line and results of the performance tests

	Left anterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.17 ± 1.23	22	15.47 ± 0.83	65	p < 0.01*
10m sprint (sec)	1.92 ± 0.14	22	1.85 ± 0.11	66	p = 0.02*
40m sprint (sec)	5.68 ± 0.42	22	5.46 ± 0.27	66	p = 0.01*
Repeated sprint (m)	706.30 ± 54.90	23	740.87 ± 34.79	63	p < 0.01*
Vertical jump (cm)	48.87 ± 7.31	23	53.97 ± 6.17	61	p < 0.01*
Pull-ups (number of)	8.67 ± 8.65	24	14.54 ± 7.93	68	p < 0.01*

* p < 0.05.

Posterior stabilizing lines

Participants who were able to hold the right posterior stabilizing line for 40 seconds did not perform significantly better ($p > 0.05$) in any of the performance tests, while participants who were able to hold the left posterior stabilizing line for 40 seconds performed significantly better ($p < 0.05$) in the vertical jump test only. These results are presented in Tables 4.14 and 4.15.

Table 4.14.: The relationship between the mean score of the right posterior stabilizing line and results of the performance tests

	Right posterior stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.11	48	15.45 ± 0.78	39	p = 0.09
10m sprint (sec)	1.88 ± 0.13	48	1.86 ± 0.11	40	p = 0.30
40m sprint (sec)	5.58 ± 0.38	48	5.45 ± 0.23	40	p = 0.06
Repeated sprint(m)	725.71 ± 49.31	49	739.46 ± 33.66	37	p = 0.15
Vertical jump (cm)	51.35 ± 6.80	46	54.05 ± 6.70	38	p = 0.07
Pull-ups (number of)	11.71 ± 8.54	51	14.63 ± 8.22	41	p = 0.10

Table 4.15: The relationship between the mean score of the left posterior stabilizing line and results of the performance tests

	Left posterior stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.69 ± 1.06	55	15.57 ± 0.86	32	p = 0.60
10m sprint (sec)	1.89 ± 0.13	55	1.84 ± 0.11	33	p = 0.06
40m sprint (sec)	5.56 ± 0.35	55	5.45 ± 0.26	33	p = 0.13
Repeated sprint(m)	732.69 ± 44.53	54	729.84 ± 42.59	32	p = 0.77
Vertical jump (cm)	51.35 ± 6.66	54	54.77 ± 6.75	30	p = 0.03*
Pull-ups (number of)	12.19 ± 8.67	57	14.34 ± 8.11	35	p = 0.24

* $p < 0.05$.

Lateral stabilizing lines

All of the performance test results differed significantly ($p < 0.05$) when comparing participants holding 40 seconds and those not holding 40 seconds on the right lateral stabilizing line. Only the repeated sprint test results differed significantly ($p < 0.05$) when comparing the two groups performing the left lateral stabilizing line. Tables 4.16 and 4.17 present these results.

Table 4.16: The relationship between the mean score of the right lateral stabilizing line and results of the performance tests

	Right lateral stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.13 ± 1.02	32	15.37 ± 0.86	55	p < 0.01*
10m sprint (sec)	1.91 ± 0.15	32	1.85 ± 0.10	56	p = 0.03*
40m sprint (sec)	5.63 ± 0.42	32	5.45 ± 0.24	56	p = 0.01*
Repeated sprint (m)	714.41 ± 52.42	34	742.88 ± 32.57	52	p < 0.01*
Vertical jump (cm)	49.45 ± 7.49	33	54.59 ± 5.60	51	p < 0.01*
Pull-ups (number of)	9.94 ± 8.10	35	14.89 ± 8.22	57	p = 0.01*

* p < 0.05.

Table 4.17: The relationship between the mean score of the left lateral stabilizing line and results of the performance tests

	Left lateral stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.80 ± 1.18	28	15.58 ± 0.88	59	p = 0.34
10m sprint (sec)	1.88 ± 0.14	28	1.87 ± 0.11	60	p = 0.58
40m sprint (sec)	5.56 ± 0.41	28	5.50 ± 0.28	60	p = 0.46
Repeated sprint (m)	714.17 ± 52.38	30	740.98 ± 35.13	56	p = 0.01*
Vertical jump (cm)	51.28 ± 7.44	29	53.25 ± 6.48	55	p = 0.21
Pull-ups (number of)	11.77 ± 9.66	31	13.64 ± 7.83	61	p = 0.32

* p < 0.05.

Medial stabilizing lines

Participants holding the right medial stabilizing line for the full 40 seconds performed significantly better ($p < 0.05$) in all the performance tests, except for the repeated sprint and vertical jump tests. Those participants able to hold the left medial stabilizing line for 40 seconds performed significantly better ($p < 0.05$) in all the performance tests. These results are presented in Tables 4.18 and 4.19.

Table 4.18: The relationship between the mean score of the right medial stabilizing line and results of the performance tests

	Right medial stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.03	62	15.25 ± 0.77	25	p = 0.02*
10m sprint (sec)	1.90 ± 0.12	63	1.80 ± 0.09	25	p < 0.01*
40m sprint (sec)	5.58 ± 0.34	63	5.37 ± 0.20	25	p = 0.01*
Repeated sprint (m)	730.40 ± 46.75	63	735.00 ± 34.11	23	p = 0.67
Vertical jump (cm)	52.19 ± 7.14	62	53.64 ± 5.99	22	p = 0.40
Pull-ups (number of)	11.59 ± 8.40	66	16.62 ± 7.71	26	p = 0.01*

* p < 0.05.

Table 4.19: The relationship between the mean score of the left medial stabilizing line of the Bunkie-test and results of the performance tests

	Left medial stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.05	57	15.34 ± 0.79	30	p = 0.04*
10m sprint (sec)	1.89 ± 0.13	58	1.83 ± 0.10	30	p = 0.02*
40m sprint (sec)	5.60 ± 0.35	58	5.36 ± 0.19	30	p < 0.01*
Repeated sprint (m)	724.31 ± 46.27	58	746.79 ± 33.28	28	p = 0.02*
Vertical jump (cm)	51.41 ± 6.87	58	55.15 ± 6.17	26	p = 0.02*
Pull-ups (number of)	11.16 ± 7.93	61	16.65 ± 8.48	31	p < 0.01*

* p < 0.05.

Front row versus backline players

The relationship between the results of the Bunkie-test and the performance tests was also determined separately for the front row and backline players. Participants were once again divided into two groups; those who were able to hold the functional lines for 40 seconds and those not able to hold the full 40 seconds. These results were compared to the results of the performance tests for each of the two groups.

A significant difference ($p < 0.05$) was found between the front row and backline players and the right posterior power line of the Bunkie-test. For those players not able to hold the Bunkie-test for 40 seconds, significant differences ($p < 0.05$) in results for the performance tests were found, except for results of the vertical jump test. These results are shown in Tables 4.20 and 4.21.

Table 4.20: The relationship between performance on the right posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**R posterior power line < 40 seconds**		**R posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.23 ± 1.06	27	15.62 ± 0.73	20	p = 0.01*
10m sprint (sec)	1.94 ± 0.13	27	1.88 ± 0.13	21	p = 0.02*
40m sprint (sec)	5.77 ± 0.37	27	5.55 ± 0.22	21	p < 0.01*
Repeated sprint (m)	706.15 ± 51.43	26	738.33 ± 32.22	21	p = 0.04*
Vertical jump (cm)	49.40 ± 7.95	25	52.32 ± 6.24	22	p = 0.33
Pull-ups (number of)	7.96 ± 6.02	28	10.57 ± 6.18	21	p = 0.01*

* $p < 0.05$.

Table 4.21: The relationship between performance on the right posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**R posterior power line < 40 seconds**		**R posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.77 ± 1.00	8	15.39 ± 0.81	32	p = 0.01*
10m sprint (sec)	1.77 ± 0.03	8	1.84 ± 0.09	32	p = 0.02*
40m sprint (sec)	5.20 ± 0.15	8	5.36 ± 0.18	32	p < 0.01*
Repeated sprint (m)	751.67 ± 43.08	9	743.00 ± 34.46	30	p = 0.04*
Vertical jump (cm)	55.00 ± 5.83	9	54.82 ± 5.58	28	p = 0.33
Pull-ups (number of)	22.22 ± 9.13	9	16.24 ± 8.13	34	p = 0.01*

* p < 0.05.

The results of the left posterior power line of the Bunkie-test, for front row players compared to backline players, showed significant differences ($p < 0.05$). Significant differences ($p < 0.05$) in results for the Illinois agility and the pull-ups tests were found between the front row and backline players. No significant differences ($p > 0.05$) were found between players able to hold 40 seconds on the line and those not able to hold 40 seconds when compared to the results of these two performance tests. See Tables 4.22 and 4.23 for these results.

Table 4.22: The relationship between performance on the left posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players

Performance tests	**L posterior power line < 40 seconds**		**L posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.15 ± 0.91	26	15.75 ± 1.02	21	p = 0.03*
10m sprint (sec)	1.92 ± 0.10	26	1.90 ± 0.16	22	p = 0.70
40m sprint (sec)	5.74 ± 0.27	26	5.60 ± 0.39	22	p = 0.11
Repeated sprint (m)	714.00 ± 47.17	25	727.95 ± 45.37	22	p = 0.06
Vertical jump (cm)	50.12 ± 6.75	25	51.50 ± 7.91	22	p = 0.80
Pull-ups (number of)	7.93 ± 4.80	27	10.50 ± 7.37	22	p = 0.02*

* p < 0.05.

Table 4.23: The relationship between performance on the left posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**L posterior power line < 40 seconds**		**L posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.81 ± 0.98	8	15.38 ± 0.83	32	p = 0.03*
10m sprint (sec)	1.82 ± 0.06	8	1.82 ± 0.09	32	p = 0.70
40m sprint (sec)	5.27 ± 0.10	8	5.34 ± 0.20	32	p = 0.11
Repeated sprint (m)	765.00 ± 24.78	8	739.84 ± 37.18	31	p = 0.06
Vertical jump (cm)	54.44 ± 5.70	9	55.00 ± 5.62	28	p = 0.80
Pull-ups (number of)	21.67 ± 10.30	9	16.38 ± 7.90	34	p = 0.02*

* p < 0.05.

A significant difference ($p < 0.05$) was found between the front row and backline players when performing the left anterior power line of the Bunkie-test. The results of the Illinois agility, repeated sprint and pull-ups tests for the front row and backline players not able to hold 40 seconds on this line differed significantly ($p < 0.05$). Tables 4.24 and 4.25 display these results. See appendix D for the table with the right anterior power line.

Table 4.24: The relationship between performance on the left anterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players

Performance tests	L anterior power line < 40 seconds		L anterior power line = 40 seconds		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.62 ± 1.06	16	15.63 ± 0.73	31	p < 0.01*
10m sprint (sec)	1.94 ± 0.16	16	1.90 ± 0.12	32	p = 0.71
40m sprint (sec)	5.82 ± 0.40	16	5.61 ± 0.27	32	p = 0.13
Repeated sprint (m)	684.12 ± 44.45	17	741.17 ± 33.21	30	p < 0.01*
Vertical jump (cm)	46.71 ± 6.88	17	53.07 ± 6.53	30	p = 0.06
Pull-ups (number of)	4.72 ± 3.68	18	11.61 ± 5.92	31	p = 0.01*

* $p < 0.05$.

Table 4.25: The relationship between performance on the left anterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	L anterior power line < 40 seconds		L anterior power line = 40 seconds		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.96 ± 0.78	6	15.32 ± 0.89	34	p < 0.01*
10m sprint (sec)	1.88 ± 0.10	6	1.81 ± 0.08	34	p = 0.71
40m sprint (sec)	5.32 ± 0.17	6	5.33 ± 0.19	34	p = 0.13
Repeated sprint (m)	769.17 ± 22.89	6	740.61 ± 36.67	33	p < 0.01*
Vertical jump (cm)	55.00 ± 4.77	6	54.84 ± 5.77	31	p = 0.06
Pull-ups (number of)	20.50 ± 8.62	6	17.00 ± 8.61	37	p = 0.01*

* $p < 0.05$.

A significant difference ($p < 0.05$) was found between the results of the front row and backline players on the right lateral stabilizing line of the Bunkie-test. When compared to the results of the 40m sprint test, significant differences ($p < 0.05$) were found between the player positions as well as between the players holding 40 seconds and those not able to hold 40 seconds. Significant differences ($p < 0.05$) were found between the results of the vertical jump test and those players not able to hold the line on the Bunkie-test for 40 seconds. See Tables 4.26 and 4.27 for these results. See appendix D for the tables for the right and left posterior stabilizing lines, as well as the left lateral stabilizing line.

Table 4.26: The relationship between performance on the right lateral stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**R lateral stabilizing line < 40 seconds**		**R lateral stabilizing line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.48 ± 0.96	20	15.59 ± 0.80	27	p = 0.21
10m sprint (sec)	1.95 ± 0.15	20	1.88 ± 0.11	28	p = 0.21
40m sprint (sec)	5.82 ± 0.40	20	5.57 ± 0.23	28	p = 0.03*
Repeated sprint (m)	697.86 ± 50.31	21	738.85 ± 33.92	26	p = 0.05
Vertical jump (cm)	46.33 ± 6.85	21	54.35 ± 5.47	26	p < 0.01*
Pull-ups (number of)	6.82 ± 5.53	22	10.93 ± 6.12	27	p = 0.78

* p < 0.05.

Table 4.27: The relationship between performance on the right lateral stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players

Performance tests	**R lateral stabilizing line < 40 seconds**				**R lateral stabilizing line = 40 seconds**				
	Mean	**±**	**SD**	**n**	**Mean**	**±**	**SD**	**n**	**p-value**
Illinois agility (sec)	15.54	±	0.86	12	15.15	±	0.88	28	p = 0.21
10m sprint (sec)	1.83	±	0.09	12	1.82	±	0.08	28	p = 0.21
40m sprint (sec)	5.32	±	0.20	12	5.33	±	0.18	28	p = 0.03*
Repeated sprint (m)	741.15	±	45.65	13	746.92	±	31.31	26	p = 0.05
Vertical jump (cm)	54.92	±	5.18	12	54.84	±	5.84	25	p < 0.01*
Pull-ups (number of)	15.23	±	9.17	13	18.47	±	8.31	30	p = 0.78

* p < 0.05.

When comparing the results of the left medial stabilizing line for the front row and backline players separately, a significant difference ($p < 0.05$) was found. Comparing the results of the performance tests to those of the Bunkie-test line, significant differences ($p < 0.05$) were found for players not able to hold 40 seconds. These were found for the 10m sprint, the 40m sprint and the pull-ups tests. Tables 4.28 and 4.29 display these results. See appendix D for table with the right medial stabilizing line.

Table 4.28: The relationship between performance on the left medial stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players

Performance tests	L medial stabilizing line < 40 seconds		L medial stabilizing line = 40 seconds		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.11 ± 1.00	38	15.38 ± 0.58	9	p = 0.06
10m sprint (sec)	1.93 ± 0.13	39	1.83 ± 0.12	9	p = 0.03*
40m sprint (sec)	5.74 ± 0.33	39	5.40 ± 0.17	9	p = 0.01*
Repeated sprint (m)	717.69 ± 48.27	39	734.38 ± 34.89	8	p = 0.89
Vertical jump (cm)	49.85 ± 7.24	39	55.25 ± 5.95	8	p = 0.14
Pull-ups (number of)	7.73 ± 4.88	40	15.11 ± 7.83	9	p = 0.02*

* $p < 0.05$.

Table 4.29: The relationship between performance on the left medial stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players

Performance tests	L medial stabilizing line < 40 seconds		L medial stabilizing line = 40 seconds		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.21 ± 0.90	19	15.32 ± 0.87	21	p = 0.06
10m sprint (sec)	1.81 ± 0.07	19	1.83 ± 0.10	21	p = 0.03*
40m sprint (sec)	5.31 ± 0.17	19	5.34 ± 0.20	21	p = 0.01*
Repeated sprint (m)	737.89 ± 39.63	19	751.75 ± 32.17	20	p = 0.89
Vertical jump (cm)	54.63 ± 4.76	19	55.11 ± 6.43	18	p = 0.14
Pull-ups (number of)	17.71 ± 8.56	21	17.27 ± 8.83	22	p = 0.02*

* $p < 0.05$.

The results of the Illinois agility and the 40m sprint tests showed a negative correlation when compared to the amount of time (< 40 seconds) each subject could hold on the medial stabilizing lines of the Bunkie-test. Thus, the subjects who were able to hold the position of the Bunkie-test for longer achieved better results in the above performance tests. The results of the repeated sprint and vertical jump tests showed a positive correlation when compared to the time on the same Bunkie-test lines. Better results in these two tests were achieved by the same players who could hold the Bunkie-test position for a longer amount of time. Another significant positive correlation ($p < 0.05$) was found when comparing the amount of time on the left medial stabilizing line to the results of the pull-ups test. See Tables 4.30 and 4.31 for these results. See appendix D for tables for results of the right and left posterior power lines, the right and left anterior power lines, the right and left posterior stabilizing lines, the right and left lateral stabilizing lines, as well as the right and left medial stabilizing lines, with the front row and backline players separately.

Table 4.30: The relationship between the amount of time (< 40 seconds) on the right medial stabilizing line of the Bunkie-test and the results of the performance tests.

	Whole group (n = 121)	
	r-value	**p-value**
Right medial stabilizing versus Illinois agility	r = -0.34	p = 0.01*
Right medial stabilizing versus 10m sprint	r = -0.16	p = 0.21
Right medial stabilizing versus 40m sprint	r = -0.32	p = 0.01*
Right medial stabilizing versus repeated sprint	r = 0.26	p = 0.04*
Right medial stabilizing versus vertical jump	r = 0.32	p = 0.01*
Right medial stabilizing versus pull-ups	r = 0.24	p = 0.05

* p < 0.05.

Table 4.31: The relationship between the amount of time (< 40 seconds) on the left medial stabilizing line of the Bunkie-test and the results of the performance tests.

	Whole group (n = 121)	
	r-value	**p-value**
Left medial stabilizing versus Illinois agility	r = -0.35	p = 0.01*
Left medial stabilizing versus 10m sprint	r = -0.25	p = 0.06
Left medial stabilizing versus 40m sprint	r = -0.33	p = 0.01*
Left medial stabilizing versus repeated sprint	r = 0.33	p = 0.01*
Left medial stabilizing versus vertical jump	r = 0.36	p = 0.01*
Left medial stabilizing versus pull-ups	r = 0.28	p = 0.03*

* $p < 0.05$.

RELATIONSHIP BETWEEN PERFORMANCES ON THE BUNKIE-TEST AND INJURY OCCURRENCE

The relationship between whether an injury was apparent (injury "yes") or not (injury "no") and the mean score on each of the functional lines of the Bunkie-test was determined. Better scores were expected when no injuries were apparent. The results are shown in Tables 4.32 and 4.33 (see appendix D for more results).

Table 4.32: Relationship between left knee injury occurrence and mean scores on the Bunkie-test

	Left knee injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 16)**	**Injury "no": Mean ± SD (n = 80)**	**p-value**
Posterior Power R	32.75 ± 12.58	32.76 ± 10.76	p = 0.92
Posterior Power L	26.44 ± 12.67	33.33 ± 11.13	p = 0.02*
Anterior Power R	37.25 ± 9.98	37.69 ± 6.36	p = 0.75
Anterior Power L	34.00 ± 12.24	36.00 ± 8.13	p = 0.37
Posterior Stab R	29.06 ± 13.73	27.54 ± 13.64	p = 0.72
Posterior Stab L	21.19 ± 14.59	26.60 ± 13.45	p = 0.14
Lateral Stab R	35.19 ± 10.69	33.65 ± 9.87	p = 0.60
Lateral Stab L	31.19 ± 12.41	34.35 ± 10.56	p = 0.27
Medial Stab R	25.38 ± 11.30	25.36 ± 12.30	p = 0.93
Medial Stab L	22.06 ± 11.92	26.60 ± 12.98	p = 0.14

* $p < 0.05$.

Table 4.33: Relationship between right shoulder injury occurrence and mean scores on the Bunkie-test

	Right shoulder injury		
Bunkie line (measured in sec	**Injury "yes": Mean ± SD (n = 14)**	**Injury "no": Mean ± SD (n = 82)**	**p-value**
Posterior Power R	28.79 ± 11.88	33.44 ± 10.79	p = 0.31
Posterior Power L	24.29 ± 14.87	33.52 ± 10.50	p = 0.01*
Anterior Power R	35.21 ± 10.41	38.02 ± 6.28	p = 0.33
Anterior Power L	35.50 ± 9.30	35.70 ± 8.89	p = 0.81
Posterior Stab R	23.43 ± 11.85	28.54 ± 13.80	p = 0.31
Posterior Stab L	18.71 ± 13.57	26.89 ± 13.46	p = 0.06**
Lateral Stab R	32.14 ± 12.53	34.21 ± 9.52	p = 0.60
Lateral Stab L	31.79 ± 13.04	34.17 ± 10.53	p = 0.58
Medial Stab R	18.50 ± 12.23	26.54 ± 11.73	p = 0.05**
Medial Stab L	19.93 ± 12.30	26.85 ± 12.75	p = 0.15

* p < 0.05.

** p < 0.1.

Participants without an injury to the left knee achieved significantly better ($p < 0.05$) scores on the left posterior power line than those with a left knee injury. Participants without a right shoulder injury also performed significantly better ($p < 0.05$) on the left posterior power line than those participants with an injury to the right shoulder. No other significant differences at a p-level of < 0.05 were found, but a few significant results were found at a p-level of < 0.1, indicating a trend towards relationships between the stabilizing lines and injuries. Relationships between the right medial stabilizing lines and the right shoulder, right ankle and right knee were found.

Due to too small sample sizes for each of the most common injury sites, the relationship between injury occurrence and performance on the Bunkie-test could not be determined for the front row and backline players separately. More significant differences can be expected if a bigger sample group should be used in a future study.

RELATIONSHIP BETWEEN BIOMOTOR ABILITIES AND INJURY OCCURRENCE

The participants with injuries were expected to perform poorly in the performance tests, as the injury and the associated biomechanical changes would hinder their performance. To determine if this was true, the relationships between injury occurrence and the results of the performance tests were determined. Only the seven most common injuries found in this study were used. Significant relationships ($p < 0.05$) were found between injuries to the right knee and the results of the Illinois agility and sprint tests. Those participants without right knee injuries performed significantly better ($p < 0.05$) in these tests. Table 4.34 displays these results. See appendix D for tables displaying the relationship between the other most common injuries and performance test results.

Table 4.34: Relationship between right knee injury occurrence and performance test results.

	Right knee injury				
Performance tests	**Injury "yes": Mean ± SD**	**n**	**Injury "no": Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.13 ± 0.88	14	15.53 ± 0.93	88	p = 0.01*
10m sprint (sec)	1.92 ± 0.11	15	1.85 ± 0.12	88	p = 0.02*
40m sprint (sec)	5.64 ± 0.36	15	5.47 ± 0.30	88	p = 0.01*
Repeated sprint (m)	726.54 ± 60.26	13	728.86 ± 40.84	83	p = 0.72
Vertical jump (cm)	52.67 ± 7.17	15	53.14 ± 6.89	83	p = 0.62
Pull-ups (number of)	11.33 ± 8.87	15	13.29 ± 8.28	89	p = 0.15

* $p < 0.05$.

The sample sizes were too small to compare the relationship between injury occurrence and performance tests with front row and backline players separately.

CHAPTER FIVE

DISCUSSION

INTRODUCTION

This study examined the relationship between the function and balance of kinetic chains, using a new isometric test, and biomotor abilities and injuries in rugby players. Various tests are used among coaches and therapists to test muscle function and biomotor abilities, but no studies have been found using tests for the balance and function of kinetic chains related to movements and relating that to performance. As more therapists realize the importance of muscles functioning in chains and not in isolation, as well as the influence of dysfunctions in these chains on biomotor abilities and performance, tests will be needed to assess these chains. This study should therefore contribute by enhancing the current knowledge base on the function of muscle chains, possible dysfunctions and the influence thereof, as well as providing a practical tool for coaches and therapists.

The main findings of this study are that players achieving times closer and equal to 40 seconds on the lines of the Bunkie-test also achieved better results in the performance tests. These significant relationships between scores on the lines of the Bunkie-test and biomotor abilities were found in almost all of the lines. The right and left anterior power lines, the right lateral stabilizing line and the left medial stabilizing line showed significant relationships with all six of the performance tests. The right and left posterior power lines both showed significant relationships with the 40m sprint test, while the right posterior power line and the left lateral stabilizing line showed significant relationships with the repeated sprint test. The left posterior stabilizing line showed a significant relationship with the vertical jump test, while the right medial stabilizing line showed significant relationships with the Illinois agility test, both of the sprint tests and the pull-ups test. Only the right posterior stabilizing line did not show significant relationships with any of the performance tests. The results suggest that there is indeed a correlation between the Bunkie-test and biomotor abilities.

The isometric Bunkie-test could be beneficial in testing fascia restrictions and the balance of kinetic chains. Because of the link between myofascia restrictions in a kinetic chain and muscle dysfunctions, is it critical that this aspect should also be tested in sports people (De Witt & Venter, 2009; Chaitow, 2007). Most tests used amongst sports people are functional tests, focusing on movement patterns and skills, or isolated muscle tests. These tests have indicated the biomotor abilities of a rugby player (Duthie *et al*., 2003: 974; Gabbett, 2005: 962; Baker & Newton, 2008: 153), but do not test for any myofascia restrictions in kinetic chains, or the balance of kinetic chains. For such a test to be of value for coaches and therapists interested in the biomotor abilities of their players, a significant relationship between the test and biomotor abilities has to be apparent. Therefore, showing that there are significant relationships between most of the lines on the Bunkie-test and biomotor abilities, as measured with performance tests, could indicate that this test can be useful in assessing the functionality of kinetic chains.

With the increased interest in connective tissue and its role in muscle function (1st International Fascia Congress, Boston, 4-5 October 2007; 2nd International Fascia Congress, Amsterdam, 27-30 October 2009) it became increasingly important to be able to test the functionality and alignment of these tissues. The unique properties of the myofascia cause it to have an influence on muscle contraction (Barnes, 1990: 5). As optimal muscle function is needed for optimal movement, any restrictions in the myofascia will influence muscle function and therefore influence an athletes' biomotor abilities. The aim of such a test would be to identify the optimal alignment of the fascia as well as restrictions that might inhibit functioning of the fascia, and then use these identified restrictions to predict performance. As injuries often occur along a restricted functional line or kinetic chain, it might also be possible to use the identified restrictions to identify weaknesses or predict injuries (Myers, 2001).

Previously, manual therapy was the preferred method to identify restrictions in the myofascia (Barnes, 1990; Chaitow, 2007). Postural analysis, functional testing and evaluation of joint symmetries were also suggested (Chaitow, 2007). None of these methods, however, included the functional lines in which movement patterns take place. Another problem was that finding the restrictions in the myofascia could not be directly related to either poor biomotor abilities or injury occurrence. The Bunkie-test of De Witt and Venter (2009) was therefore a possible test for fascia restrictions among athletes utilizing movement patterns, as it is based on the functional lines of Myers (2001) and is supposed to test the function of fascia in these specific functional lines or kinetic chains of the body.

When rugby became a professional sport, more demands were placed on players to perform well and when injured, to return to play as soon as possible. The result was higher intensity and more frequent training sessions, placing strain on the musculoskeletal system of each player. A high injury occurrence rate was evident among rugby players at all levels (Gabbett, 2003; Gabbett *et al*., 2008). Various studies have been conducted to identify the causes of these injuries. The impact of tackling (Clark *et al*, 1990; Gabbett, 2003), overexertion and overuse due to higher-intensity training (Gabbett, 2004b; Bathgate *et al*, 2002) were some of the most common causes. Performance tests for biomotor abilities and isolated muscle tests are popular among coaches and therapists working with rugby players. Identifying weaknesses in performance and in isolated muscles has not been completely successful in eliminating injury. Functioning of the core muscles and balance of kinetic chains are important in an asymmetrical sport such as rugby, as all the kinetic chains are not used to the same degree, but balance is still necessary for the whole musculoskeletal system to function optimally. At least one test for muscle balance in the kinetic chains should therefore be included in a standard test battery for rugby players.

RESEARCH QUESTIONS

Three research questions were raised and motivated this study. Based on the test results, each of these questions could be answered and will be discussed under the following headings.

IS THERE A RELATIONSHIP BETWEEN FASCIA RESTRICTIONS, AS ASSESSED BY THE BUNKIE-TEST, AND SELECTED BIOMOTOR ABILITIES IN RUGBY PLAYERS?

Poor performance on any of the Bunkie-test lines could indicate a restriction in the fascia in that specific line. As stated earlier, optimal movement is dependant on a well-distributed, non-restricted fascia throughout the body (Barnes, 1990; Järvinen et al., 2002). To successfully execute the skills required at the elite level of rugby, such as sprinting, changing direction at a fast pace and jumping, optimal muscle function is needed. The assumption was made that poor results on the Bunkie-test lines would indicate poor biomotor abilities and thus poor results in the performance tests.

Four of the functional lines of the Bunkie-test, namely the right and left anterior power lines, the right lateral stabilizing line and the left medial stabilizing line, showed significant relationships with all of the performance tests. This might indicate that restrictions in these four lines could influence biomotor abilities negatively. The right and left posterior power lines, the left lateral stabilizing line and the right medial stabilizing line showed significant relationships when compared to the results of the sprint tests.

The anterior power lines of the Bunkie-test were derived from the superficial front line of Myers' (2001, 2009) original lines. The movement function of these lines involves forward trunk flexion and sudden, strong movements, which are the most common movements required by rugby players and specifically in most of the performance tests. The function of the medial stabilizing lines, based on Myers' deep front lines, are to oppose and balance the lateral lines, mainly in the legs (Myers, 2001: 217). This could explain why the opposite lateral and medial line showed significant relationships to the same performance tests. If restrictions were found in one of the lateral lines, the opposing medial line would also be affected; therefore both would be expected to show poor results on the Bunkie-test.

The relationship between the performance test results and the Bunkie-test results were also determined separately for the front row and backline players. Both of these groups were again divided into two groups, those players able to hold the full 40 seconds on each functional line and those players not able to hold 40 seconds. Significant differences were found between the results of the front row and backline players for the posterior power lines, the left anterior power line, the right lateral stabilizing line and the left medial stabilizing line. Another finding was that the significant differences between the two groups were mainly for those participants not able to hold 40 seconds. Very few differences were found in biomotor abilities between the front row and backline players who were able to hold the Bunkie-test lines for the full 40 seconds.

The above again indicates the importance for sports people to have no fascia restrictions in any of the functional lines, as the alignment of the lines influence each other and significantly influence the ability of the player to perform optimally. If a player can hold each of the functional lines for the full 40 seconds (which is required at an elite level), they are expected to perform better regarding biomotor abilities, whether they are a front row or a backline player. This was confirmed by the fact that almost no significant differences were found between front row and backline players who could hold the full 40 seconds.

The high amount of significant findings when comparing the Bunkie-test with biomotor abilities in rugby players suggests that the Bunkie-tests might be used as a testing tool for rugby coaches and trainers. The results achieved could then indicate restricted functional lines in each player and therefore also the player's biomotor and performance ability. More research is needed on a bigger sample group to confirm the above findings and to determine which Bunkie-line(s) correlates to which biomotor abilities, if applicable.

IS THERE A RELATIONSHIP BETWEEN FASCIA RESTRICTIONS, AS ASSESSED BY THE BUNKIE-TEST, AND INJURY OCCURRENCE IN RUGBY PLAYERS?

Analyzing the relationships between the most common injury occurrences and results of the Bunkie-test for the whole group showed few significant findings. Those players without injury were expected to achieve better results on the functional lines of the Bunkie-test. The only significant relationships were found between injuries to the left knee and results for the left posterior power line, as well as between injuries to the right shoulder and results for the left posterior power line. It seemed that, in spite of any current injuries, the participants were still able to perform well on the Bunkie-test.

The fact that there were so few significant findings might have been due to a variety of factors, one being the limited sample size for each injury (specified according to site and according to the OSICS system). Another possibility is that the Bunkie-test is not useful as a predictor of current injury occurrence. In a sports team the coach should be aware of all current injuries and therefore would not need a test to identify them. The Bunkie-test would thus be necessary to predict future injuries and not to identify current injuries. Poor results for any line of the Bunkie-test indicated restrictions in the fascia and thus a weakness in that specific line. Therefore it would be assumed that, if not treated or attended to, this weakness would eventually result in injury. To validate the use of the Bunkie-test to identify current weaknesses and possible future injury sites, the Bunkie-test would have to be conducted at the start of the season and again at a later stage or at the end of the season. The injuries acquired during the season should be noted and a significant relationship between them and the initial poorer results on Bunkie-test lines might be evident then.

IS THERE A RELATIONSHIP BETWEEN FASCIA RESTRICTIONS, AS ASSESSED BY THE BUNKIE-TEST, AND THE SITE(S) OF INJURY IN RUGBY PLAYERS?

Significant relationships were found between injuries to the left knee and right shoulder, and the left posterior power line of the Bunkie-test. These were the only significant findings and could be coincidental. No clear trends for specific injury sites relating to the results of the Bunkie-test were found. At a significance level of $p < 0.1$, relationships between the right medial stabilizing line and injuries to the right shoulder, the right ankle and the right knee were found.

THE RELATIONSHIP BETWEEN BIOMOTOR ABILITIES AND INJURY OCCURRENCE

Any injury to a joint, ligament or muscle will inhibit the coordinated effective movement patterns of the body necessary for biomotor abilities at a high sports level. Gabbett and Domrow (2005) investigated the link between biomotor abilities and injury occurrence by using standard performance tests. They found that players with poor scores on the 10m and 40m sprint tests and on the aerobic fitness test had a higher occurrence of injuries.

In the present study, the incidence of injuries to specific joints was identified, not just injuries in general. This caused the sample sizes for each injury site to be small. The only significant relationships found were between participants with injuries to the right knee and performance on the Illinois agility and sprint tests, as well as between injuries to the lower back and the 10m sprint and vertical jump tests.

The relationships found between knee injuries and biomotor abilities on those skill tests requiring more speed and agility were probably due to the important role the knee joint and surrounding muscles play in these types of movements. The impact on the body and especially the lower back when performing a jumping activity might explain the relationship between lower back injuries and performance on the vertical jump test. As for the 10m sprint test, the initial start of any sprint is in a slightly bent-over position and requires core strength, both of which could be influenced by injuries to the lower back.

Bigger sample sizes are needed in future research to identify relationships between specific injuries and specific biomotor abilities. Due to the differences in biomotor abilities between front row and backline players, these groups should be analyzed separately using far larger sample groups.

CONCLUSION

No previous research has been reported on the relationship between the functioning of fascia lines and biomotor abilities in athletes, or on any tests for fascia restrictions pertaining to sports performance. The main finding of this study is that restrictions in the fascia, as measured by the isometric Bunkie-test, influence biomotor abilities in rugby players.

The influence of the fascia on muscle function is well-documented. The existence of kinetic muscle chains and a continuity of fascia along these lines, as well as the balance of these lines, both play a role in muscle function. Restrictions in one or more of the kinetic chains might influence muscle activation and function when movements are executed. Repetitive movements with these problematic kinetic chains force the body to rely on compensatory actions of muscles. Continuing over a period of time, this might result in poorer performance or injuries. As muscle function is required for all movements and an even more optimal muscle function is required for complex and repetitive movement patterns in sport, it is important for coaches and therapists to be able to test for all the factors influencing muscle function. To test the readiness of rugby players to compete and to identify the best players for a team, coaches typically use a battery of performance and isolated muscle tests on a regular basis. Little attention is given to the function and balance of the core, fascia lines and muscles in their kinetic chains, despite the importance of these structures in movement.

The Bunkie-test was designed to test fascia restrictions along kinetic chains, although more research is needed to determine its validity. This test could be ideal for coaches and therapists, such as Biokineticists, to use as part of a test battery for sports people or to confirm that an athlete can return to his or her sport. No other tests for the function of most of the kinetic chains along fascial lines and the balance of these lines have been found. Manual palpation is often prescribed to assess restrictions in the fascia lines, but a more practical test which can be performed by athletes is needed.

Significant relationships were found between the Bunkie-test and biomotor abilities, measured with standard performance tests. Players with restricted fascia in a kinetic chain obtained poorer results in the performance tests. This could indicate that restricted fascia lines, resulting in dysfunctional kinetic chains, might influence biomotor abilities in rugby players. The Bunkie-test can be a useful tool in identifying weaknesses and imbalances in the kinetic chains of each player, thereby giving coaches and therapists a chance to rectify them before they lead to deteriorating biomotor abilities, poorer performance and eventually injury. The Bunkie-test is a relatively simple test. Players should also be able to work in pairs and assess themselves, once they have learned the testing procedures.

Results from this study suggest that athletes with restricted kinetic chains demonstrate poorer biomotor abilities, but whether it also results in the increased occurrence of injuries could not be shown. When determining the relationships between the Bunkie-test and injury occurrences, significant relationships were only found between injuries to the left knee and the right shoulder and performance on the left posterior power line. As the Bunkie-test consists of ten functional lines and the occurrence of seven different injuries was investigated, this was not regarded as a significant finding. Larger sample sizes might yield different results. It was expected to find a relationship between injury occurrence and performance on the stabilizing lines, but more significant findings were found in the power lines. Injures players did not participate, possible influencing the outcome.

This is the first study to determine the presence of a link between fascia restrictions along specific kinetic chains in the body, and biomotor abilities in athletes. It relates the numerous numbers of studies on fascia and muscle function to athletes, helping coaches to identify a possible cause for poor biomotor abilities and performance in their players. Based on the findings of this study, the Bunkie-test could be included in a test battery for rugby players, preferably at the beginning and middle of the season.

STUDY LIMITATIONS

A limitation of this study was the sample size. Dividing the subjects into groups according to performance and Bunkie-test results formed slightly smaller than expected groups. Injuries were divided according to injury site, which decreased the sample sizes for each injury, probably limiting the amount of significant findings. During the statistical analysis a wide variety of relationships were determined, increasing the chance of false findings. This should be considered when reviewing the findings.

Another limitation of this study was that testing was conducted at different locations and in subsequent weeks. The same protocol, order of procedures and one researcher as overseer were used to standardize the testing as far as possible, but slight differences might still have occurred. Players from three rugby academies were used and even though they used similar types of training programs, there were slight differences. The same tests should be conducted on a group of players training under exactly the same circumstances. Significant findings should therefore be confirmed with more studies.

RECOMMENDATIONS FOR FUTURE RESEARCH

The Bunkie-test has been used in clinical practice for about 12 years (De Witt & Venter, 2009), and many positive reports are given by athletes from various disciplines. Results from this exploratory study warrant further research into this relatively new area for sport scientists.

In order to validate the use of the Bunkie-test for athletes, more studies should be done on this subject. Conducting the same tests on larger sample sizes should help determine relationships between each of the functional lines of the Bunkie-test and specific biomotor abilities, specific injuries or injury sites. Subjects from different sport disciplines could also be tested.

Following this study, the next step would be to use the Bunkie-test to identify fascia restrictions, investigate effective ways to treat them through intervention and then re-test participants once again using the Bunkie-test.

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APPENDIX A

LETTER OF PERMISSION TO RUGBY CLUBS

March 2009

To whom it may concern,

I am planning to do my Masters Degree at the University of Stellenbosch under the supervision of dr. Ranel Venter.

Preliminary title: "The relationship between the Bunkie-test and selected biomotor abilities in elite-level rugby players."

What the study consists of: In the last year or two the role of the fascia (the connective tissue between muscles) on muscle functioning became increasingly important. The fascia can restrict muscles in such a way that the muscles cannot function effectively. This then leads to compensation in the muscular system and eventually to injuries. I want to test the alignment and restrictions in the fascia of each rugby player, as well as conduct a few functional performance tests. Each player will also be required to complete a short injury questionnaire. Using statistics, correlations between the fascia restrictions, the performance tests and injuries will be determined.

What I require: I require only the willingness of each player to partake in the above mentioned tests once. These will be conducted in the middle of the rugby season. The functional performance test battery will consist of standard tests which are often used among rugby players.

What are the advantages for the players? Participation in this study will require very little of their time as testing will only be done once. Previous studies on fascia confirmed that it does play an important role in muscle function. If a correlation is found between fascia restrictions and / or performance and / or injuries, the fascia test can be used in the future as part of a test battery to determine or predict possible weaknesses and / or injuries.

Please do not hesitate to contact me if you have any questions.

Danel van Pletzen

E-mail: danel.bio@mtnloaded.co.za

APPENDIX B
INFORMED CONSENT FORM

THE RELATIONSHIP BETWEEN THE BUNKIE-TEST AND SELECTED BIOMOTOR ABILITIES IN ELITE-LEVEL RUGBY PLAYERS

You are asked to participate in a research study conducted by Danél van Pletzen (B.Sc. Hons. Biokinetics), from the Department of Sport Science at Stellenbosch University. The results of this study will contribute to a thesis for a Masters degree. You were selected as a participant in this study because you are part of a rugby academy and you are playing rugby at an elite level this year.

1. PURPOSE OF THE STUDY

The purpose of this study is to determine whether fascia alignment has any influence on biomotor abilities and injury occurrence.

2. PROCEDURES

We request your participation in various tests during June of 2009:

1. The Bunkie-test (measuring fascia alignment)
2. Illinois agility test (measuring agility)
3. 10m and 40m sprint test (measuring speed)
4. Repeated sprint test (measuring speed endurance)
5. Vertical jump (measuring explosive leg power)
6. Wide-grip pull ups (measuring upper body muscle endurance)

You will also be asked to fill in a short questionnaire regarding your current injury status.

The above tests will only be conducted only once for the purpose of this study and will take place at your rugby academy over a period of 1 week (except if you are a member of the Stellenbosch Rugby Academy, in which case the testing will be at SUSPI at the University of Stellenbosch). The testing will be coordinated to form part of your training requirements at the academy and will not require extra time or sacrifices on your behalf.

3. POTENTIAL RISKS AND DISCOMFORTS

All tests are approved standard rugby tests, except for the Bunkie-test, which consist of holding different static positions for 40seconds each. There is no indicated risk involved in participating in this study.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

No immediate benefits will be obtained from participating in this study, but if a correlation is found between the results on the Bunkie-test and injury occurrence and/or performance tests, injury prevention and even rehabilitation among rugby players will benefit substantially.

5. PAYMENT FOR PARTICIPATION

No remuneration will be received for participation in this study.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Only the test administrators and the primary researchers will have access to the test results. In the final thesis, only the results will be published and no names of participants will be mentioned.

7. PARTICIPATION AND WITHDRAWAL

You may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if you acquire any injuries that may inhibit your performance on the required tests.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Danél van Pletzen or the project leader, dr. R. Venter.

Danél van Pletzen
Tel: 021 – 872 2236 (w)
E-mail: danel.bio@mtnloaded.co.za

Dr. R. Venter
Tel: 021 – 808 4721 (w)
E-mail: rev@sun.ac.za

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Maryke Hunte-Husselmann at the Unit for Research Development.

Maryke Hunte-Husselman
Tel: 021 – 808 4623
E-mail: mh3@sun.ac.za

SIGNATURE OF RESEARCH SUBJECT

The information above was described to me, ______________________ by Danél van Pletzen in English or Afrikaans and I am in command of this. I was given the opportunity to ask questions and these questions were answered to my satisfaction. I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

____

Name of Subject/Participant

____ _________

Signature of Subject/Participant **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to __________________. He was encouraged and given ample time to ask me any questions. This conversation was conducted in Afrikaans or English and no translator was used.

____ _________

Signature of Investigator **Date**

APPENDIX C

INJURY QUESTIONNAIRE

One purpose of this study is to investigate a possible correlation between your fascia alignment (using the Bunkie-test) and minor or chronic injuries you have obtained. To make an accurate conclusion, we need a **complete list of all your current injuries**. Please provide as much details as possible, specify which joint / muscle and if it is / was a chronic or traumatic injury, e.g.

- Left shoulder – chronic injury – bothersome during / after training since August 2008, but does not influence my ability to train and participate in games.

or

- Right knee – traumatic injury – strained hamstring muscle at the end of the season in 2008 – had rehabilitation, but is bothersome from time to time when doing speed work.

or

- Lower back – no specific incident, just general lower backache sometimes during and after contact training sessions or games.

Name: ______________________________

Age: _____

Date: __________

Position: __________________________

Played since: __________

Operations: __________________________ (joint / muscle + date)

Injuries: ____

____

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APPENDIX D

TABLES

RELATIONSHIP BETWEEN PERFORMANCES ON THE BUNKIE-TEST AND THE RESULTS OF THE PERFORMANCE TESTS

Mean and standard deviation for each functional line of the Bunkie-test

Functional line	Mean ± SD (seconds)
Posterior power line (right)	32.8 ± 10.98
Posterior Power line (left)	32.3 ± 11.58
Anterior power line (right)	37.6 ± 7.00
Anterior power line (left)	35.7 ± 8.86
Posterior stabilizing line (right)	27.6 ± 13.64
Posterior stabilizing line (left)	25.7 ± 13.65
Lateral stabilizing line (right)	34.0 ± 9.93
Lateral stabilizing line (left)	33.9 ± 10.85
Medial stabilizing line (right)	25.5 ± 12.05
Medial stabilizing line (left)	26.0 ± 12.87

Participants able to hold the positions of the Bunkie-test for 40 seconds compared to participants not able to hold the position for 40 seconds

Functional line of the Bunkie-test	= 40 seconds	< 40 seconds
Posterior power line (right)	60%	38%
Posterior power line (left)	60%	38%
Anterior power line (right)	83%	15%
Anterior power line (left)	73%	25%
Posterior stabilizing line (right)	42% *	56% *
Posterior stabilizing line (left)	36% *	62% *
Lateral stabilizing line (right)	62%	36%
Lateral stabilizing line (left)	66%	32%
Medial stabilizing line (right)	26% *	72% *
Medial stabilizing line (left)	32% *	66% *

Percentages might not add up to 100% due to rounding off.

* More participants not able to hold position for 40 seconds

Relationship between front row and backline players for the functional lines of the Bunkie-test

Variable (measured in seconds)	Front row players Mean ± SD (n = 51)	Backline players Mean ± SD (n = 45)	p-value
Posterior power line (right)	29.27 ± 12.37	36.71 ± 7.61	p < 0.01*
Posterior power line (left)	29.02 ± 12.46	35.76 ± 9.50	p = 0.01*
Anterior power line (right)	35.63 ± 9.21	39.87 ± 0.66	p < 0.01*
Anterior power line (left)	33.94 ± 10.15	37.62 ± 6.82	p = 0.05
Posterior stabilizing line (right)	25.20 ± 14.24	30.73 ± 12.33	p = 0.05
Posterior stabilizing line (left)	23.71 ± 13.48	27.96 ± 13.77	p = 0.22
Lateral stabilizing line (right)	32.65 ± 11.22	35.33 ± 8.22	p = 0.16
Lateral stabilizing line (left)	32.37 ± 12.36	35.47 ± 8.78	p = 0.19
Medial stabilizing line (right)	21.55 ± 12.58	29.69 ± 9.97	p < 0.01*
Medial stabilizing line (left)	21.51 ± 12.56	30.76 ± 11.46	p < 0.01*

* p < 0.05.

Mean and standard deviation for each of the performance tests

Performance test	Mean ± SD
Illinois agility (seconds)	15.6 ± 0.94
10m sprint (seconds)	1.9 ± 0.12
40m sprint (seconds)	5.5 ± 0.31
Repeated sprint (meters)	728.5 ± 43.58
Vertical jump (centimeters)	53.1 ± 6.90
Pull-ups (number of)	13.0 ± 8.35

Relationship between front row and backline players for the performance tests

Performance test	Front row players Mean ± SD	Backline players Mean ± SD	p-value
Illinois agility (sec)	15.97 ± 0.97 (n = 47)	15.27 ± 0.88 (n = 40)	p < 0.01*
10m sprint (sec)	1.91 ± 0.13 (n = 48)	1.82 ± 0.08 (n = 40)	p < 0.01*
40m sprint (sec)	5.68 ± 0.33 (n = 48)	5.33 ± 0.18 (n = 40)	p < 0.01*
Repeated sprint (m)	720.53 ± 46.37 (n = 47)	745.00 ± 36.20 (n = 39)	p = 0.01*
Vertical jump (cm)	50.77 ± 7.27 (n = 47)	54.86 ± 5.56 (n = 37)	p = 0.01*
Pull-ups (number of)	9.08 ± 6.16 (n = 49)	17.49 ± 8.60 (n = 43)	p < 0.01*

* p < 0.05.

Injury occurrence rate in percentage

Injury site	**Whole group (n = 121)**	**Front row players (n = 65)**	**Backline players (n = 56)**	**p-value**
Left shoulder (S)	19 (16%)	13 (20%)	6 (11%)	p = 0.16
Right ankle (A)	19 (16%)	11 (17%)	8 (14%)	p = 0.69
Left knee (K)	18 (15%)	9 (14%)	9 (16%)	p = 0.73
Right knee (K)	16 (13%)	7 (11%)	9 (16%)	p = 0.39
Lower back (L)	15 (12%)	9 (14%)	6 (11%)	p = 0.60
Right shoulder (S)	14 (11%)	10 (15%)	4 (7%)	p = 0.15
Left ankle (A)	12 (10%)	8 (12%)	4 (7%)	p = 0.34

The relationship between the mean score of the right posterior power line and results of the performance tests

	Right posterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.90 ± 1.20	35	15.48 ± 0.78	52	$p = 0.05$
10m sprint (sec)	1.90 ± 0.14	35	1.85 ± 0.11	53	$p = 0.07$
40m sprint (sec)	5.64 ± 0.41	35	5.43 ± 0.22	53	$p < 0.01$*
Repeated sprint (m)	717.86 ± 52.81	35	741.08 ± 33.31	51	$p = 0.01$*
Vertical jump (cm)	50.88 ± 7.78	34	53.72 ± 5.95	50	$p = 0.06$
Pull-ups (number of)	11.43 ± 9.17	37	14.07 ± 7.89	55	$p = 0.14$

* $p < 0.05$.

The relationship between the mean score of the left posterior power line and results of the performance tests

	Left posterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.83 ± 1.08	34	15.53 ± 0.92	53	$p = 0.16$
10m sprint (sec)	1.90 ± 0.10	34	1.86 ± 0.13	54	$p = 0.13$
40m sprint (sec)	5.63 ± 0.31	34	5.45 ± 0.31	54	$p = 0.01$*
Repeated sprint (m)	726.36 ± 47.91	33	734.91 ± 40.79	53	$p = 0.38$
Vertical jump (cm)	51.26 ± 6.69	34	53.46 ± 6.88	50	$p = 0.15$
Pull-ups (number of)	11.36 ± 8.82	36	14.07 ± 8.16	56	$p = 0.14$

* $p < 0.05$.

The relationship between the mean score of the right anterior power line and results of the performance tests

	Right anterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.70 ± 0.98	12	15.48 ± 0.89	75	p < 0.01*
10m sprint (sec)	1.95 ± 0.16	12	1.86 ± 0.11	76	p = 0.01*
40m sprint (sec)	5.88 ± 0.44	12	5.46 ± 0.26	76	p < 0.01*
Repeated sprint (m)	684.29 ± 53.06	14	740.83 ± 35.09	72	p < 0.01*
Vertical jump (cm)	47.15 ± 7.68	13	53.56 ± 6.25	71	p < 0.01*
Pull-ups (number of)	4.43 ± 3.69	14	14.56 ± 8.18	78	p < 0.01*

* $p < 0.05$.

The relationship between the mean score of the left anterior power line and results of the performance tests

	Left anterior power line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.17 ± 1.23	22	15.47 ± 0.83	65	p < 0.01*
10m sprint (sec)	1.92 ± 0.14	22	1.85 ± 0.11	66	p = 0.02*
40m sprint (sec)	5.68 ± 0.42	22	5.46 ± 0.27	66	p = 0.01*
Repeated sprint (m)	706.30 ± 54.90	23	740.87 ± 34.79	63	p < 0.01*
Vertical jump (cm)	48.87 ± 7.31	23	53.97 ± 6.17	61	p < 0.01*
Pull-ups (number of)	8.67 ± 8.65	24	14.54 ± 7.93	68	p < 0.01*

* $p < 0.05$.

The relationship between the mean score of the right posterior stabilizing line and results of the performance tests

	Right posterior stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.11	48	15.45 ± 0.78	39	p = 0.09
10m sprint (sec)	1.88 ± 0.13	48	1.86 ± 0.11	40	p = 0.30
40m sprint (sec)	5.58 ± 0.38	48	5.45 ± 0.23	40	p = 0.06
Repeated sprint(m)	725.71 ± 49.31	49	739.46 ± 33.66	37	p = 0.15
Vertical jump (cm)	51.35 ± 6.80	46	54.05 ± 6.70	38	p = 0.07
Pull-ups (number of)	11.71 ± 8.54	51	14.63 ± 8.22	41	p = 0.10

The relationship between the mean score of the left posterior stabilizing line and results of the performance tests

	Left posterior stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.69 ± 1.06	55	15.57 ± 0.86	32	p = 0.60
10m sprint (sec)	1.89 ± 0.13	55	1.84 ± 0.11	33	p = 0.06
40m sprint (sec)	5.56 ± 0.35	55	5.45 ± 0.26	33	p = 0.13
Repeated sprint(m)	732.69± 44.53	54	729.84± 42.59	32	p = 0.77
Vertical jump (cm)	51.35 ± 6.66	54	54.77 ± 6.75	30	p = 0.03*
Pull-ups (number of)	12.19 ± 8.67	57	14.34 ± 8.11	35	p = 0.24

* $p < 0.05$.

The relationship between the mean score of the right lateral stabilizing line and results of the performance tests

	Right lateral stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.13 ± 1.02	32	15.37 ± 0.86	55	p < 0.01*
10m sprint (sec)	1.91 ± 0.15	32	1.85 ± 0.10	56	p = 0.03*
40m sprint (sec)	5.63 ± 0.42	32	5.45 ± 0.24	56	p = 0.01*
Repeated sprint (m)	714.41±52.42	34	742.88± 32.57	52	p < 0.01*
Vertical jump (cm)	49.45 ± 7.49	33	54.59 ± 5.60	51	p < 0.01*
Pull-ups (number of)	9.94 ± 8.10	35	14.89 ± 8.22	57	p = 0.01*

* p < 0.05.

The relationship between the mean score of the left lateral stabilizing line and results of the performance tests

	Left lateral stabilizing line				
Performance tests	**< 40 seconds** **Mean ± SD**	**n**	**= 40 seconds** **Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.80 ± 1.18	28	15.58 ± 0.88	59	p = 0.34
10m sprint (sec)	1.88 ± 0.14	28	1.87 ± 0.11	60	p = 0.58
40m sprint (sec)	5.56 ± 0.41	28	5.50 ± 0.28	60	p = 0.46
Repeated sprint (m)	714.17 ±52.38	30	740.98± 35.13	56	p = 0.01*
Vertical jump (cm)	51.28 ± 7.44	29	53.25 ± 6.48	55	p = 0.21
Pull-ups (number of)	11.77 ± 9.66	31	13.64 ± 7.83	61	p = 0.32

* p < 0.05.

The relationship between the mean score of the right medial stabilizing line and results of the performance tests

	Right medial stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.03	62	15.25 ± 0.77	25	p = 0.02*
10m sprint (sec)	1.90 ± 0.12	63	1.80 ± 0.09	25	p < 0.01*
40m sprint (sec)	5.58 ± 0.34	63	5.37 ± 0.20	25	p = 0.01*
Repeated sprint (m)	730.40± 46.75	63	735.00± 34.11	23	p = 0.67
Vertical jump (cm)	52.19 ± 7.14	62	53.64 ± 5.99	22	p = 0.40
Pull-ups (number of)	11.59 ± 8.40	66	16.62 ± 7.71	26	p = 0.01*

* p < 0.05.

The relationship between the mean score of the left medial stabilizing line and results of the performance tests

	Left medial stabilizing line				
Performance tests	**< 40 seconds Mean ± SD**	**n**	**= 40 seconds Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.81 ± 1.05	57	15.34 ± 0.79	30	p = 0.04*
10m sprint (sec)	1.89 ± 0.13	58	1.83 ± 0.10	30	p = 0.02*
40m sprint (sec)	5.60 ± 0.35	58	5.36 ± 0.19	30	p < 0.01*
Repeated sprint (m)	724.31± 46.27	58	746.79± 33.28	28	p = 0.02*
Vertical jump (cm)	51.41 ± 6.87	58	55.15 ± 6.17	26	p = 0.02*
Pull-ups (number of)	11.16 ± 7.93	61	16.65 ± 8.48	31	p < 0.01*

* p < 0.05.

The relationship between performance on the right posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**R posterior power line < 40 seconds**		**R posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.23 ± 1.06	27	15.62 ± 0.73	20	p = 0.01*
10m sprint (sec)	1.94 ± 0.13	27	1.88 ± 0.13	21	p = 0.02*
40m sprint (sec)	5.77 ± 0.37	27	5.55 ± 0.22	21	p < 0.01*
Repeated sprint (m)	706.15 ± 51.43	26	738.33 ± 32.22	21	p = 0.04*
Vertical jump (cm)	49.40 ± 7.95	25	52.32 ± 6.24	22	p = 0.33
Pull-ups (number of)	7.96 ± 6.02	28	10.57 ± 6.18	21	p = 0.01*

* $p < 0.05$.

The relationship between performance on the right posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**R posterior power line < 40 seconds**		**R posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.77 ± 1.00	8	15.39 ± 0.81	32	p = 0.01*
10m sprint (sec)	1.77 ± 0.03	8	1.84 ± 0.09	32	p = 0.02*
40m sprint (sec)	5.20 ± 0.15	8	5.36 ± 0.18	32	p < 0.01*
Repeated sprint (m)	751.67 ± 43.08	9	743.00 ± 34.46	30	p = 0.04*
Vertical jump (cm)	55.00 ± 5.83	9	54.82 ± 5.58	28	p = 0.33
Pull-ups (number of)	22.22 ± 9.13	9	16.24 ± 8.13	34	p = 0.01*

* $p < 0.05$.

The relationship between performance on the left posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**L posterior power line < 40 seconds**		**L posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.15 ± 0.91	26	15.75 ± 1.02	21	p = 0.03*
10m sprint (sec)	1.92 ± 0.10	26	1.90 ± 0.16	22	p = 0.70
40m sprint (sec)	5.74 ± 0.27	26	5.60 ± 0.39	22	p = 0.11
Repeated sprint (m)	714.00 ± 47.17	25	727.95 ± 45.37	22	p = 0.06
Vertical jump (cm)	50.12 ± 6.75	25	51.50 ± 7.91	22	p = 0.80
Pull-ups (number of)	7.93 ± 4.80	27	10.50 ± 7.37	22	p = 0.02*

* $p < 0.05$.

The relationship between performance on the left posterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**L posterior power line < 40 seconds**		**L posterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.81 ± 0.98	8	15.38 ± 0.83	32	p = 0.03*
10m sprint (sec)	1.82 ± 0.06	8	1.82 ± 0.09	32	p = 0.70
40m sprint (sec)	5.27 ± 0.10	8	5.34 ± 0.20	32	p = 0.11
Repeated sprint (m)	765.00 ± 24.78	8	739.84 ± 37.18	31	p = 0.06
Vertical jump (cm)	54.44 ± 5.70	9	55.00 ± 5.62	28	p = 0.80
Pull-ups (number of)	21.67 ± 10.30	9	16.38 ± 7.90	34	p = 0.02*

* $p < 0.05$.

The relationship between performance on the right anterior power line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the front row players.

Performance tests	**R anterior power line < 40seconds**		**R anterior power line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.81 ± 1.04	10	15.74 ± 0.83	37	p = 0.78
10m sprint (sec)	1.97 ± 0.17	10	1.90 ± 0.12	38	p = 0.59
40m sprint (sec)	5.96 ± 0.44	10	5.60 ± 0.26	38	p = 0.31
Repeated sprint (m)	672.08 ± 46.68	12	737.14 ± 33.04	35	p = 0.01
Vertical jump (cm)	45.91 ± 7.73	11	52.25 ± 6.54	36	p = 0.29
Pull-ups (number of)	3.83 ± 2.98	12	10.78 ± 5.98	37	p = 0.59

* $p < 0.05$

The relationship between performance on the right anterior power line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the backline players.

Performance tests	**R anterior power line < 40seconds**		**R anterior power line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.11 ± 0.09	2	15.22 ± 0.88	38	p = 0.78
10m sprint (sec)	1.85 ± 0.04	2	1.82 ± 0.09	38	p = 0.59
40m sprint (sec)	5.47 ± 0.04	2	5.32 ± 0.18	38	p = 0.31
Repeated sprint (m)	757.50 ± 10.61	2	744.32 ± 37.03	37	p = 0.01
Vertical jump (cm)	54.00 ± 0.00	2	54.91 ± 5.72	35	p = 0.29
Pull-ups (number of)	8.00 ± 7.07	2	17.95 ± 8.46	41	p = 0.59

* $p < 0.05$

The relationship between performance on the left anterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**L anterior power line < 40 seconds**		**L anterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.62 ± 1.06	16	15.63 ± 0.73	31	p < 0.01*
10m sprint (sec)	1.94 ± 0.16	16	1.90 ± 0.12	32	p = 0.71
40m sprint (sec)	5.82 ± 0.40	16	5.61 ± 0.27	32	p = 0.13
Repeated sprint (m)	684.12 ± 44.45	17	741.17 ± 33.21	30	p < 0.01*
Vertical jump (cm)	46.71 ± 6.88	17	53.07 ± 6.53	30	p = 0.06
Pull-ups (number of)	4.72 ± 3.68	18	11.61 ± 5.92	31	p = 0.01*

* p < 0.05.

The relationship between performance on the left anterior power line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**L anterior power line < 40 seconds**		**L anterior power line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	14.96 ± 0.78	6	15.32 ± 0.89	34	p < 0.01*
10m sprint (sec)	1.88 ± 0.10	6	1.81 ± 0.08	34	p = 0.71
40m sprint (sec)	5.32 ± 0.17	6	5.33 ± 0.19	34	p = 0.13
Repeated sprint (m)	769.17 ± 22.89	6	740.61 ± 36.67	33	p < 0.01*
Vertical jump (cm)	55.00 ± 4.77	6	54.84 ± 5.77	31	p = 0.06
Pull-ups (number of)	20.50 ± 8.62	6	17.00 ± 8.61	37	p = 0.01*

* p < 0.05.

The relationship between performance on the right posterior stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the front row players.

Performance tests	**R posterior stabilizing line < 40seconds**		**R posterior stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.14 ± 1.06	30	15.66 ± 0.70	17	p = 0.20
10m sprint (sec)	1.93 ± 0.14	30	1.89 ± 0.13	18	p = 0.31
40m sprint (sec)	5.74 ± 0.37	30	5.58 ± 0.24	18	p = 0.11
Repeated sprint (m)	712.17 ± 51.34	30	735.29 ± 32.28	17	p = 0.14
Vertical jump (cm)	49.62 ± 7.31	29	52.61 ± 7.01	18	p = 0.51
Pull-ups (number of)	7.68 ± 5.44	31	11.50 ± 6.72	18	p = 0.14

* $p < 0.05$.

The relationship between performance on the right posterior stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the backline players.

Performance tests	**R posterior stabilizing line < 40seconds**		**R posterior stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.25 ± 0.97	18	15.29 ± 0.82	22	p = 0.20
10m sprint (sec)	1.81 ± 0.09	18	1.83 ± 0.08	22	p = 0.31
40m sprint (sec)	5.31 ± 0.21	18	5.34 ± 0.16	22	p = 0.11
Repeated sprint (m)	747.11 ± 38.05	19	743.00 ± 35.22	20	p = 0.14
Vertical jump (cm)	54.29 ± 4.69	17	55.35 ± 6.29	20	p = 0.51
Pull-ups (number of)	17.95 ± 8.81	20	17.09 ± 8.59	23	p = 0.14

* $p < 0.05$.

The relationship between performance on the left posterior stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the front row players.

Performance tests	**L posterior stabilizing line < 40seconds**		**L posterior stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.03 ± 1.02	34	15.82 ± 0.85	13	p = 0.27
10m sprint (sec)	1.93 ± 0.13	34	1.87 ± 0.12	14	p = 0.34
40m sprint (sec)	5.72 ± 0.34	34	5.58 ± 0.29	14	p = 0.12
Repeated sprint (m)	720.15 ± 45.93	34	721.54 ± 49.39	13	p = 0.31
Vertical jump (cm)	49.70 ± 7.23	33	53.29 ± 6.99	14	p = 0.62
Pull-ups (number of)	8.03 ± 5.04	35	11.71 ± 7.96	14	p = 0.05

* $p < 0.05$

The relationship between performance on the left posterior stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the backline players.

Performance tests	**L posterior stabilizing line < 40seconds**		**L posterior stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.14 ± 0.91	21	15.41 ± 0.84	19	p = 0.27
10m sprint (sec)	1.83 ± 0.08	21	1.82 ± 0.09	19	p = 0.34
40m sprint (sec)	5.30 ± 0.17	21	5.36 ± 0.20	19	p = 0.12
Repeated sprint (m)	754.00 ± 33.27	20	735.53 ± 37.60	19	p = 0.31
Vertical jump (cm)	53.95 ± 4.73	21	56.06 ± 6.46	21	p = 0.62
Pull-ups (number of)	18.82 ± 9.19	22	16.10 ± 7.91	21	p = 0.05

* $p < 0.05$

The relationship between performance on the right lateral stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**R lateral stabilizing line < 40 seconds**		**R lateral stabilizing line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.48 ± 0.96	20	15.59 ± 0.80	27	p = 0.21
10m sprint (sec)	1.95 ± 0.15	20	1.88 ± 0.11	28	p = 0.21
40m sprint (sec)	5.82 ± 0.40	20	5.57 ± 0.23	28	p = 0.03*
Repeated sprint (m)	697.86 ± 50.31	21	738.85 ± 33.92	26	p = 0.05
Vertical jump (cm)	46.33 ± 6.85	21	54.35 ± 5.47	26	p < 0.01*
Pull-ups (number of)	6.82 ± 5.53	22	10.93 ± 6.12	27	p = 0.78

* p < 0.05.

The relationship between performance on the right lateral stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**R lateral stabilizing line < 40 seconds**		**R lateral stabilizing line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.54 ± 0.86	12	15.15 ± 0.88	28	p = 0.21
10m sprint (sec)	1.83 ± 0.09	12	1.82 ± 0.08	28	p = 0.21
40m sprint (sec)	5.32 ± 0.20	12	5.33 ± 0.18	28	p = 0.03*
Repeated sprint (m)	741.15 ± 45.65	13	746.92 ± 31.31	26	p = 0.05
Vertical jump (cm)	54.92 ± 5.18	12	54.84 ± 5.84	25	p < 0.01*
Pull-ups (number of)	15.23 ± 9.17	13	18.47 ± 8.31	30	p = 0.78

* p < 0.05.

The relationship between performance on the left lateral stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the front row players.

Performance tests	**L lateral stabilizing line < 40seconds**		**L lateral stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.29 ± 1.08	17	15.79 ± 0.87	30	p = 0.06
10m sprint (sec)	1.94 ± 0.15	17	1.90 ± 0.12	31	p = 0.20
40m sprint (sec)	5.73 ± 0.41	17	5.64 ± 0.28	31	p = 0.21
Repeated sprint (m)	695.83 ± 50.01	18	735.86 ± 37.13	29	p = 0.06
Vertical jump (cm)	47.71 ± 7.63	17	52.50 ± 6.57	30	p = 0.02*
Pull-ups (number of)	6.89 ± 4.83	19	10.47 ± 6.57	30	p = 0.06

* $p < 0.05$

The relationship between performance on the left lateral stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the backline players.

Performance tests	**L lateral stabilizing line < 40seconds**		**L lateral stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.03 ± 0.94	11	15.36 ± 0.85	29	p = 0.06
10m sprint (sec)	1.80 ± 0.05	11	1.83 ± 0.09	29	p = 0.20
40m sprint (sec)	5.28 ± 0.18	11	5.35 ± 0.18	29	p = 0.21
Repeated sprint (m)	741.67 ± 44.64	12	746.48 ± 32.63	27	p = 0.06
Vertical jump (cm)	56.33 ± 2.96	12	54.16 ± 6.39	25	p = 0.02*
Pull-ups (number of)	19.50 ± 10.48	12	16.71 ± 7.81	31	p = 0.06

* $p < 0.05$

The relationship between performance on the right medial stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the front row players.

Performance tests	**R medial stabilizing line < 40seconds**		**R medial stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.12 ± 1.02	37	15.40 ± 0.46	10	p = 0.22
10m sprint (sec)	1.93 ± 0.13	38	1.83 ± 0.11	10	p = 0.34
40m sprint (sec)	5.73 ± 0.34	38	5.45 ± 0.20	10	p = 0.05
Repeated sprint (m)	720.26 ± 49.44	38	721.67 ± 32.50	9	p = 0.86
Vertical jump (cm)	50.08 ± 7.43	38	53.67 ± 6.08	9	p = 0.10
Pull-ups (number of)	7.56 ± 4.79	39	15.00 ± 7.53	10	p = 0.04*

* $p < 0.05$

The relationship between performance on the right medial stabilizing line of the Bunkie-test (40seconds vs. <40seconds) and results of performance tests for the backline players.

Performance tests	**R medial stabilizing line < 40seconds**		**R medial stabilizing line = 40seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.33 ± 0.86	25	15.16 ± 0.93	15	p = 0.22
10m sprint (sec)	1.84 ± 0.08	25	1.79 ± 0.07	15	p = 0.34
40m sprint (sec)	5.34 ± 0.19	25	5.31 ± 0.18	15	p = 0.05
Repeated sprint (m)	745.80 ± 38.32	25	743.57 ± 33.42	14	p = 0.86
Vertical jump (cm)	55.54 ± 5.22	24	53.62 ± 6.17	13	p = 0.10
Pull-ups (number of)	17.41 ± 9.14	27	17.63 ± 7.89	16	p = 0.04*

* $p < 0.05$

The relationship between performance on the left medial stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the front row players.

Performance tests	**L medial stabilizing line < 40 seconds**		**L medial stabilizing line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	16.11 ± 1.00	38	15.38 ± 0.58	9	p = 0.06
10m sprint (sec)	1.93 ± 0.13	39	1.83 ± 0.12	9	p = 0.03*
40m sprint (sec)	5.74 ± 0.33	39	5.40 ± 0.17	9	p = 0.01*
Repeated sprint (m)	717.69 ± 48.27	39	734.38 ± 34.89	8	p = 0.89
Vertical jump (cm)	49.85 ± 7.24	39	55.25 ± 5.95	8	p = 0.14
Pull-ups (number of)	7.73 ± 4.88	40	15.11 ± 7.83	9	p = 0.02*

* p < 0.05.

The relationship between performance on the left medial stabilizing line of the Bunkie-test (40 seconds vs. < 40 seconds) and results of performance tests for the backline players.

Performance tests	**L medial stabilizing line < 40 seconds**		**L medial stabilizing line = 40 seconds**		
	Mean ± SD	**n**	**Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	15.21 ± 0.90	19	15.32 ± 0.87	21	p = 0.06
10m sprint (sec)	1.81 ± 0.07	19	1.83 ± 0.10	21	p = 0.03*
40m sprint (sec)	5.31 ± 0.17	19	5.34 ± 0.20	21	p = 0.01*
Repeated sprint (m)	737.89 ± 39.63	19	751.75 ± 32.17	20	p = 0.89
Vertical jump (cm)	54.63 ± 4.76	19	55.11 ± 6.43	18	p = 0.14
Pull-ups (number of)	17.71 ± 8.56	21	17.27 ± 8.83	22	p = 0.02*

* p < 0.05.

The relationship between the amount of time (< 40 seconds) on the right posterior power line of the Bunkie-test and the results of the performance tests.

Right posterior power line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.16	p = 0.35	r = -0.10	p = 0.82	r = -0.07	p = 0.74
10m sprint	r = -0.09	p = 0.59	r = 0.70	p = 0.05**	r = 0.02	p = 0.93
40m sprint	r = -0.11	p = 0.54	r = 0.40	p = 0.33	r = 0.01	p = 0.94
Repeated sprint	r = 0.06	p = 0.73	r = -0.42	p = 0.25	r = 0.15	p = 0.46
Vertical jump	r = 0.17	p = 0.32	r = 0.11	p = 0.77	r = 0.16	p = 0.43
Pull-ups	r = 0.12	p = 0.48	r = 0.49	p = 0.18	r = 0.02	p = 0.92

** Significant correlation at $p < 0.1$.

The relationship between the amount of time (< 40 seconds) on the left posterior power line of the Bunkie-test and the results of the performance tests.

Left posterior power line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.04	p = 0.83	r = 0.16	p = 0.71	r = 0.01	p = 0.95
10m sprint	r = 0.03	p = 0.87	r = 0.49	p = 0.21	r = -0.06	p = 0.77
40m sprint	r = -0.04	p = 0.82	r = 0.57	p = 0.14	r = 0.02	p = 0.91
Repeated sprint	r = 0.25	p = 0.15	r = -0.21	p = 0.62	r = 0.27	p = 0.20
Vertical jump	r = 0.31	p = 0.07**	r = 0.20	p = 0.61	r = 0.44	p = 0.03*
Pull-ups	r = 0.02	p = 0.92	r = -0.29	p = 0.44	r = 0.09	p = 0.64

* $p < 0.05$

** Significant correlation at $p < 0.1$.

The relationship between the amount of time (< 40 seconds) on the right anterior power line of the Bunkie-test and the results of the performance tests.

Right anterior power line	**Front row (n = 65)**	
	r-value	**p-value**
Illinois agility	r = -0.49	p = 0.15
10m sprint	r = 0.00	p = 1.00
40m sprint	r = -0.44	p = 0.20
Repeated sprint	r = 0.29	p = 0.35
Vertical jump	r = 0.23	p = 0.49
Pull-ups	r = 0.58	p = 0.05**

** Significant correlation at p < 0.1.

The relationship between the amount of time (< 40 seconds) on the left anterior power line of the Bunkie-test and the results of the performance tests.

Left anterior power line	**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.23	p = 0.66	r = -0.41	p = 0.12
10m sprint	r = 0.03	p = 0.96	r = -0.18	p = 0.50
40m sprint	r = -0.36	p = 0.49	r = -0.24	p = 0.36
Repeated sprint	r = 0.60	p = 0.21	r = 0.00	p = 0.99
Vertical jump	r = -0.20	p = 0.70	r = 0.33	p = 0.20
Pull-ups	r = -0.06	p = 0.91	r = 0.19	p = 0.44

The relationship between the amount of time (< 40 seconds) on the right posterior stabilizing line of the Bunkie-test and the results of the performance tests.

Right posterior stabilizing line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.06	p = 0.68	r = 0.19	p = 0.46	r = -0.09	p = 0.63
10m sprint	r = -0.06	p = 0.70	r = 0.16	p = 0.52	r = -0.05	p = 0.80
40m sprint	r = -0.16	p = 0.27	r = 0.08	p = 0.77	r = -0.16	p = 0.41
Repeated sprint	r = -0.03	p = 0.85	r = -0.29	p = 0.23	r = 0.02	p = 0.91
Vertical jump	r = 0.02	p = 0.92	r = -0.28	p = 0.28	r = 0.07	p = 0.71
Pull-ups	r = 0.06	p = 0.67	r = 0.01	p = 0.98	r = -0.02	p = 0.91

The relationship between the amount of time (< 40 seconds) on the left posterior stabilizing line of the Bunkie-test and the results of the performance tests.

Left posterior stabilizing line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.02	p = 0.86	r = 0.00	p = 0.99	r = -0.11	p = 0.54
10m sprint	r = 0.01	p = 0.96	r = -0.17	p = 0.46	r = 0.02	p = 0.93
40m sprint	r = 0.01	p = 0.96	r = -0.17	p = 0.46	r = -0.06	p = 0.74
Repeated sprint	r = 0.17	p = 0.22	r = -0.04	p = 0.88	r = 0.34	p = 0.05
Vertical jump	r = 0.10	p = 0.47	r = 0.16	p = 0.50	r = 0.23	p = 0.19
Pull-ups	r = -0.11	p = 0.40	r = -0.15	p = 0.50	r = -0.02	p = 0.92

The relationship between the amount of time (< 40 seconds) on the right lateral stabilizing line of the Bunkie-test and the results of the performance tests.

Right lateral stabilizing line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = 0.14	p = 0.40	r = -0.30	p = 0.35	r = 0.31	p = 0.19
10m sprint	r = 0.02	p = 0.92	r = -0.45	p = 0.15	r = 0.17	p = 0.48
40m sprint	r = -0.05	p = 0.77	r = -0.57	p = 0.05**	r = -0.06	p = 0.80
Repeated sprint	r = -0.03	p = 0.86	r = -0.05	p = 0.88	r = 0.04	p = 0.86
Vertical jump	r = -0.36	p = 0.04*	r = 0.17	p = 0.59	r = -0.48	p = 0.03*
Pull-ups	r = -0.05	p = 0.77	r = 0.55	p = 0.05**	r = -0.25	p = 0.25

* $p < 0.05$

** Significant correlation at $p < 0.1$.

The relationship between the amount of time (< 40 seconds) on the left lateral stabilizing line of the Bunkie-test and the results of the performance tests.

Left lateral stabilizing line	**Whole sample (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.16	p = 0.41	r = -0.25	p = 0.47	r = -0.11	p = 0.69
10m sprint	r = -0.13	p = 0.52	r = 0.38	p = 0.25	r = -0.24	p = 0.35
40m sprint	r = -0.21	p = 0.28	r = 0.27	p = 0.41	r = -0.35	p = 0.16
Repeated sprint	r = -0.08	p = 0.69	r = -0.06	p = 0.85	r = -0.05	p = 0.85
Vertical jump	r = 0.00	p = 0.98	r = -0.46	p = 0.13	r = 0.08	p = 0.77
Pull-ups	r = 0.15	p = 0.41	r = -0.08	p = 0.81	r = 0.24	p = 0.32

The relationship between the amount of time (< 40 seconds) on the right medial stabilizing line of the Bunkie-test and the results of the performance tests.

Right medial stabilizing line	**Whole group (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.34	p = 0.01*	r = -0.23	p = 0.26	r = -0.25	p = 0.14
10m sprint	r = -0.16	p = 0.21	r = 0.12	p = 0.58	r = -0.07	p = 0.69
40m sprint	r = -0.32	p = 0.01*	r = 0.11	p = 0.61	r = -0.26	p = 0.12
Repeated sprint	r = 0.26	p = 0.04*	r = -0.04	p = 0.85	r = 0.36	p = 0.03
Vertical jump	r = 0.32	p = 0.01*	r = 0.20	p = 0.35	r = 0.23	p = 0.16
Pull-ups	r = 0.24	p = 0.05	r = -0.14	p = 0.50	r = 0.25	p = 0.12

* $p < 0.05$.

The relationship between the amount of time (< 40 seconds) on the left medial stabilizing line of the Bunkie-test and the results of the performance tests.

Left medial stabilizing line	**Whole group (n = 121)**		**Backline (n = 56)**		**Front row (n = 65)**	
	r-value	**p-value**	**r-value**	**p-value**	**r-value**	**p-value**
Illinois agility	r = -0.35	p = 0.01*	r = -0.05	p = 0.84	r = -0.44	p = 0.01*
10m sprint	r = -0.25	p = 0.06	r = -0.10	p = 0.68	r = -0.20	p = 0.22
40m sprint	r = -0.33	p = 0.01*	r = -0.23	p = 0.35	r = -0.36	p = 0.02*
Repeated sprint	r = 0.33	p = 0.01*	r = 0.02	p = 0.94	r = 0.43	p = 0.01*
Vertical jump	r = 0.36	p = 0.01*	r = 0.22	p = 0.36	r = 0.41	p = 0.01*
Pull-ups	r = 0.28	p = 0.03*	r = -0.15	p = 0.51	r = 0.37	p = 0.02*

* $p < 0.05$.

Relationship between right knee injury occurrence and mean scores on the Bunkie-test

	Right knee injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 12)**	**Injury "no": Mean ± SD (n = 53)**	**p-value**
Posterior Power R	31.33 ± 3.35	30.96 ± 1.68	p = 0.92
Posterior Power L	28.17 ± 3.64	30.22 ± 1.83	p = 0.62
Anterior Power R	34.50 ± 2.30	37.90 ± 1.16	p = 0.19
Anterior Power L	34.83 ± 2.90	34.79 ± 1.46	p = 0.99
Posterior Stab R	25.92 ± 4.00	24.79 ± 2.01	p = 0.80
Posterior Stab L	20.33 ± 3.89	22.93 ± 1.96	p = 0.55
Lateral Stab R	30.33 ± 3.21	32.66 ± 1.61	p = 0.52
Lateral Stab L	35.67 ± 3.39	31.33 ± 1.70	p = 0.26
Medial Stab R	17.25 ± 3.12	23.56 ± 1.57	p = 0.08**
Medial Stab L	17.42 ± 2.88	20.32 ± 1.45	p = 0.37

** $p < 0.1$.

Relationship between left knee injury occurrence and mean scores on the Bunkie-test

	Left knee injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 16)**	**Injury "no": Mean ± SD (n = 80)**	**p-value**
Posterior Power R	32.75 ± 12.58	32.76 ± 10.76	p = 0.92
Posterior Power L	26.44 ± 12.67	33.33 ± 11.13	p = 0.02*
Anterior Power R	37.25 ± 9.98	37.69 ± 6.36	p = 0.75
Anterior Power L	34.00 ± 12.24	36.00 ± 8.13	p = 0.37
Posterior Stab R	29.06 ± 13.73	27.54 ± 13.64	p = 0.72
Posterior Stab L	21.19 ± 14.59	26.60 ± 13.45	p = 0.14
Lateral Stab R	35.19 ± 10.69	33.65 ± 9.87	p = 0.60
Lateral Stab L	31.19 ± 12.41	34.35 ± 10.56	p = 0.27
Medial Stab R	25.38 ± 11.30	25.36 ± 12.30	p = 0.93
Medial Stab L	22.06 ± 11.92	26.60 ± 12.98	p = 0.14

* $p < 0.05$.

Relationship between right shoulder injury occurrence and mean scores on the Bunkie-test

	Right shoulder injury		
Bunkie line (measured in sec	**Injury "yes": Mean ± SD (n = 14)**	**Injury "no": Mean ± SD (n = 82)**	**p-value**
Posterior Power R	28.79 ± 11.88	33.44 ± 10.79	p = 0.31
Posterior Power L	24.29 ± 14.87	33.52 ± 10.50	p = 0.01*
Anterior Power R	35.21 ± 10.41	38.02 ± 6.28	p = 0.33
Anterior Power L	35.50 ± 9.30	35.70 ± 8.89	p = 0.81
Posterior Stab R	23.43 ± 11.85	28.54 ± 13.80	p = 0.31
Posterior Stab L	18.71 ± 13.57	26.89 ± 13.46	p = 0.06**
Lateral Stab R	32.14 ± 12.53	34.21 ± 9.52	p = 0.60
Lateral Stab L	31.79 ± 13.04	34.17 ± 10.53	p = 0.58
Medial Stab R	18.50 ± 12.23	26.54 ± 11.73	p = 0.05**
Medial Stab L	19.93 ± 12.30	26.85 ± 12.75	p = 0.15

* $p < 0.05$.

** $p < 0.1$.

The relationship between left shoulder injury occurrence and mean scores on the Bunkie-test

	Left shoulder injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 18)**	**Injury "no": Mean ± SD (n = 78)**	**p-value**
Posterior Power R	32.58 ± 2.52	33.09 ± 1.19	p = 0.86
Posterior Power L	30.07 ± 2.68	32.91 ± 1.27	p = 0.34
Anterior Power R	38.64 ± 1.62	37.55 ± 0.77	p = 0.54
Anterior Power L	35.94 ± 2.11	35.75 ± 1.00	p = 0.94
Posterior Stab R	28.47 ± 3.23	27.85 ± 1.52	p = 0.86
Posterior Stab L	21.61 ± 3.25	26.78 ± 1.53	p = 0.16
Lateral Stab R	35.32 ± 2.39	33.69 ± 1.13	p = 0.54
Lateral Stab L	33.16 ± 2.61	34.09 ± 1.23	p = 0.75
Medial Stab R	24.83 ± 2.76	25.79 ± 1.30	p = 0.75
Medial Stab L	24.61 ± 2.91	26.47 ± 1.37	p = 0.56

Relationship between right ankle injury occurrence and mean scores on the Bunkie-test

	Right ankle injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 18)**	**Injury "no": Mean ± SD (n = 78)**	**p-value**
Posterior Power R	30.97 ± 2.46	33.46 ± 1.18	p = 0.36
Posterior Power L	30.43 ± 2.64	32.84 ± 1.27	p = 0.41
Anterior Power R	36.85 ± 1.59	37.95 ± 0.77	p = 0.53
Anterior Power L	36.59 ± 2.07	35.59 ± 1.00	p = 0.66
Posterior Stab R	25.08 ± 3.16	28.63 ± 1.52	p = 0.31
Posterior Stab L	23.73 ± 3.22	26.31 ± 1.55	p = 0.47
Lateral Stab R	32.04 ± 2.34	34.44 ± 1.13	p = 0.36
Lateral Stab L	34.95 ± 2.57	33.68 ± 1.23	p = 0.66
Medial Stab R	21.06 ± 2.66	26.67 ± 1.28	p = 0.06**
Medial Stab L	25.46 ± 2.86	26.29 ± 1.37	p = 0.79

** $p < 0.1$.

Relationship between left ankle injury occurrence and mean scores on the Bunkie-test

	Left ankle injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 10)**	**Injury "no": Mean ± SD (n = 86)**	**p-value**
Posterior Power R	32.34 ± 3.32	33.07 ± 1.13	p = 0.84
Posterior Power L	34.08 ± 3.55	32.19 ± 1.21	p = 0.62
Anterior Power R	34.31 ± 2.11	38.14 ± 0.72	p = 0.09**
Anterior Power L	35.97 ± 2.79	35.76 ± 0.95	p = 0.94
Posterior Stab R	30.56 ± 4.25	27.67 ± 1.45	p = 0.52
Posterior Stab L	29.04 ± 4.32	25.46 ± 1.47	p = 0.44
Lateral Stab R	30.46 ± 3.14	34.40 ± 1.07	p = 0.24
Lateral Stab L	32.20 ± 3.45	34.12 ± 1.17	p = 0.60
Medial Stab R	20.50 ± 3.60	26.21 ± 1.23	p = 0.14
Medial Stab L	26.73 ± 3.84	26.06 ± 1.31	p = 0.87

** $p < 0.1$.

Relationship between lower back injury occurrence and mean scores on the Bunkie-test

	Lower back injury		
Bunkie line (measured in sec)	**Injury "yes": Mean ± SD (n = 13)**	**Injury "no": Mean ± SD (n = 83)**	**p-value**
Posterior Power R	37.81 ± 2.87	32.25 ± 1.13	p = 0.07**
Posterior Power L	34.64 ± 3.12	32.04 ± 1.23	p = 0.44
Anterior Power R	38.65 ± 1.88	37.61 ± 0.74	p = 0.61
Anterior Power L	36.82 ± 2.45	35.62 ± 0.97	p = 0.65
Posterior Stab R	26.63 ± 3.74	28.17 ± 1.48	p = 0.70
Posterior Stab L	24.56 ± 3.81	26.03 ± 1.50	p = 0.72
Lateral Stab R	36.79 ± 2.76	33.56 ± 1.09	p = 0.28
Lateral Stab L	34.90 ± 3.03	33.77 ± 1.20	p = 0.73
Medial Stab R	27.18 ± 3.19	25.38 ± 1.26	p = 0.60
Medial Stab L	25.52 ± 3.37	26.23 ± 1.33	p = 0.85

** $p < 0.1$.

Relationship between right knee injury occurrence and performance test results

Performance tests	**Injury**	**Injury "yes": Mean ± SD**	**n**	**Injury "no": Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	Right knee	16.13 ± 0.88	14	15.53 ± 0.93	88	p = 0.01*
10m sprint (sec)	Right knee	1.92 ± 0.11	15	1.85 ± 0.12	88	p = 0.02*
40m sprint (sec)	Right knee	5.64 ± 0.36	15	5.47 ± 0.30	88	p = 0.01*
Repeated sprint (m)	Right knee	726.54 ± 60.26	13	728.86 ± 40.84	83	p = 0.72
Vertical jump (cm)	Right knee	52.67 ± 7.17	15	53.14 ± 6.89	83	p = 0.62
Pull-ups (number of)	Right knee	11.33 ± 8.87	15	13.29 ± 8.28	89	p = 0.15

* $p < 0.05$.

Relationship between left knee injury occurrence and performance test results

Variable	**Injury**	**Injury yes: Mean ± SD**	**n**	**Injury no: Mean ± SD**	**n**	**p-value**
Illinois agility (sec)	L knee	15.44 ± 0.24	14	15.61 ± 0.09	88	p = 0.50
10m sprint (sec)	L knee	1.87 ± 0.03	14	1.86 ± 0.01	89	p = 0.69
40m sprint (sec)	L knee	5.42 ± 0.07	14	5.50 ± 0.03	89	p = 0.29
Repeated sprint (m)	L knee	744.54 ± 11.23	14	726.96 ± 4.65	82	p = 0.15
Vertical jump (cm)	L knee	52.89 ± 1.76	14	53.37 ± 0.72	84	p = 0.80
Pull-ups (number of)	L knee	14.36 ± 1.86	14	13.37 ± 0.77	84	p = 0.62

Relationship between right shoulder injury occurrence and performance test results

Variable	Injury	Injury yes: Mean ± SD	n	Injury no: Mean ± SD	n	p-value
Illinois agility (sec)	R shoulder	15.30 ± 0.25	13	15.63 ± 0.09	89	p = 0.23
10m sprint (sec)	R shoulder	1.85 ± 0.03	13	1.86 ± 0.01	90	p = 0.75
40m sprint (sec)	R shoulder	5.48 ± 0.08	13	5.49 ± 0.03	90	p = 0.91
Repeated sprint (m)	R shoulder	732.13 ± 12.01	13	729.12 ± 4.66	83	p = 0.82
Vertical jump (cm)	R shoulder	54.10 ± 1.85	13	53.18 ± 0.72	85	p = 0.64
Pull-ups (number of)	R shoulder	12.89 ± 2.02	13	13.60 ± 0.76	91	p = 0.74

Relationship between left shoulder injury occurrence and performance test results

Variable	Injury	Injury yes: Mean ± SD	n	Injury no: Mean ± SD	n	p-value
Illinois agility (sec)	L shoulder	15.53 ± 0.21	18	15.60 ± 0.10	84	p = 0.77
10m sprint (sec)	L shoulder	1.90 ± 0.03	18	1.85 ± 0.01	85	p = 0.14
40m sprint (sec)	L shoulder	5.50 ± 0.06	18	5.48 ± 0.03	85	p = 0.82
Repeated sprint (m)	L shoulder	739.84 ± 10.91	16	727.56 ± 4.72	80	p = 0.31
Vertical jump (cm)	L shoulder	51.57 ± 1.63	17	53.64 ± 0.73	81	p = 0.25
Pull-ups (number of)	L shoulder	12.83 ± 1.84	16	13.63 ± 0.77	88	p = 0.69

Relationship between right ankle injury occurrence and performance test results

Variable	Injury	Injury yes: Mean ± SD	n	Injury no: Mean ± SD	n	p-value
Illinois agility (sec)	R ankle	15.65 ± 0.22	17	15.57 ± 0.10	85	p = 0.73
10m sprint (sec)	R ankle	1.86 ± 0.03	18	1.86 ± 0.01	85	p = 0.96
40m sprint (sec)	R ankle	5.52 ± 0.06	18	5.48 ± 0.03	85	p = 0.52
Repeated sprint (m)	R ankle	722.32 ± 10.29	17	731.04 ± 4.77	79	p = 0.44
Vertical jump (cm)	R ankle	52.65 ± 1.61	17	53.43 ± 0.73	81	p = 0.66
Pull-ups (number of)	R ankle	10.82 ± 1.68	18	14.07 ± 0.77	86	p = 0.08

Relationship between left ankle injury occurrence and performance test results

Variable	Injury	Injury yes: Mean ± SD	n	Injury no: Mean ± SD	n	p-value
Illinois agility (sec)	L ankle	15.67 ± 0.28	10	15.58 ± 0.09	92	p = 0.75
10m sprint (sec)	L ankle	1.84 ± 0.04	10	1.86 ± 0.01	93	p = 0.59
40m sprint (sec)	L ankle	5.48 ± 0.09	10	5.49 ± 0.03	93	p = 0.91
Repeated sprint (m)	L ankle	717.90 ± 12.27	12	731.13 ± 4.61	84	p = 0.31
Vertical jump (cm)	L ankle	52.69 ± 2.00	11	53.37 ± 0.71	87	p = 0.75
Pull-ups (number of)	L ankle	12.27 ± 2.18	11	13.65 ± 0.75	93	p = 0.55

Relationship between lower back injury occurrence and performance test results

Variable	Injury	Injury yes: Mean ± SD	n	Injury no: Mean ± SD	n	p-value
Illinois agility (sec)	Lower back	15.61 ± 0.26	12	15.58 ± 0.09	90	p = 0.92
10m sprint (sec)	Lower back	1.80 ± 0.03	13	1.87 ± 0.01	90	p < 0.05*
40m sprint (sec)	Lower back	5.39 ± 0.07	13	5.50 ± 0.03	90	p = 0.18
Repeated sprint (m)	Lower back	743.53 ± 11.71	13	727.35 ± 4.62	83	p = 0.20
Vertical jump (cm)	Lower back	56.84 ± 1.79	13	52.77 ± 0.70	85	p < 0.05*
Pull-ups (number of)	Lower back	14.16 ± 2.01	13	13.42 ± 0.76	91	p = 0.73

* p < 0.05